WATER QUALITY CONSTRAINTS ON THE
USE OF A RECREATIONAL IMPOUNDMENT
IN NORTHERN ARIZONA

Technical Completion Report

WATER QUALITY CONSTRAINTS ON THE USE OF A RECREATIONAL IMPOUNDMENT IN NORTHERN ARIZONA

Eisenhower Consortium Grant 262
USDA-RMF&RES 16-803-GR

Charles C. Avery
School of Forestry
Northern Arizona University
Flagstaff, AZ 86001

1 April 1981

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract

WATER QUALITY CONSTRAINTS ON THE USE

OF A RECREATIONAL IMPOUNDMENT IN NORTHERN ARIZONA

Ashurst Lake is a small (160 acres) recreational impoundment in Coconino County, Arizona, which is regionally known as an excellent trout fishery. It is also like several other highly-productive trout lakes in Utah and Arizona, very susceptible to algae blooms, and thus to oxygen depletion and consequent fish kills.

This study attempted to assess the historical and hydrologic setting of the lakes, and to assemble physical and chemical descriptions for 1978. A thorough examination of the characteristics of the surrounding watershed was also undertaken.

Because of the ecological nature of the lake itself, as well as its recreational value, several slight but significant changes in its management setting are suggested which might forestall its rapid eutrophication.

Eisenhower Consortium Grant 262
to Charles C. Avery
NAU School of Forestry, Flagstaff
draft report submitted 1 Aug. 1980;
revised Nov. 1980; final report
submitted 1 April 1981

INTRODUCTION

This research project focused on Ashurst Lake, a recreation impoundment in Coconino County, Arizona, and had the following two objectives:

1. To monitor changes in the physicochemical water quality of Ashurst Lake and in an adjacent impoundment, Coconino Reservoir, throughout the summer of 1978;
2. To assess the characteristics of the vegetation on the watersheds of both impoundments;

Additionally, it was hoped that the research might identify a principal cause for the deteriorating quality of Ashurst Lake as a cold-water fishery.

Water-based recreation is becoming an increasingly important aspect of outdoor leisure activities, and in northern Arizona certain small lakes have a high value as recreation resources. At the same time, concern for the long-term well-being of the natural environment, and consequently for appropriate management strategies aimed at preserving the quality of these waters has risen dramatically as a public issue.

Since 1958 Ashurst Lake has been subject to periodic algal blooms, and in 1974 the concentration of blue-green algae was apparently sufficient to cause heavy mortality in the stocked rainbow trout population (Schwartz, 1976). In July 1975 an experimental application of Simazine (commercially labeled as Aquazine) resulted in the virtual elimination of the blue-green algae, and in the restoration of the lake as a viable fishery; however, the underlying cause for this algal bloom was not investigated. In 1979 another algal bloom occurred, although it proved not to be as destructive

to the fish population as was the 1974 bloom. While repeated treatment of the algal blooms with Simazine or another algicide might prove to be effective in periodically controlling the build-up of such populations, it also appears that other less costly and more permanent alternatives should be investigated, and that the basis for formulating such alternatives rests upon an understanding of the characteristics of the lake and its surroundings.

DESCRIPTION AND DEVELOPMENT OF ASHURST LAKE

Ashurst Lake is the result of a natural depression occurring on a rather flat mesa located near the southern edge of the Colorado Plateau, in southcentral Coconino County, Arizona (Figure 1). There are several other water bodies located in the general region of Ashurst Lake, two of which are, Mormon Lake and Lake Mary. These lakes attract numerous visitors to this region.

A 7.5 minute series topographic quadrangle (Ashurst Lake-1962) depicts the immediate region surrounding the investigation site (Figure 2). Anderson Mesa, the mesa on which the lake is found, extends about 20 miles in a southeasterly direction from its origin, which is about 6 miles south of Flagstaff, until it gradually gives way to steeper topography. Ashurst Lake (longitude 35^{o} 01'N, latitude 111^{o} 23'N) is about 23 road miles south-east of Flagstaff: it is located in Sections 13,14,23 and 24 of T19N, R9E and has an (indicated) elevation of 7,114 feet.

Anderson Mesa is directly to the east of the Walnut Canyon fault, a graben fault which is responsible for the present location of Lake Mary

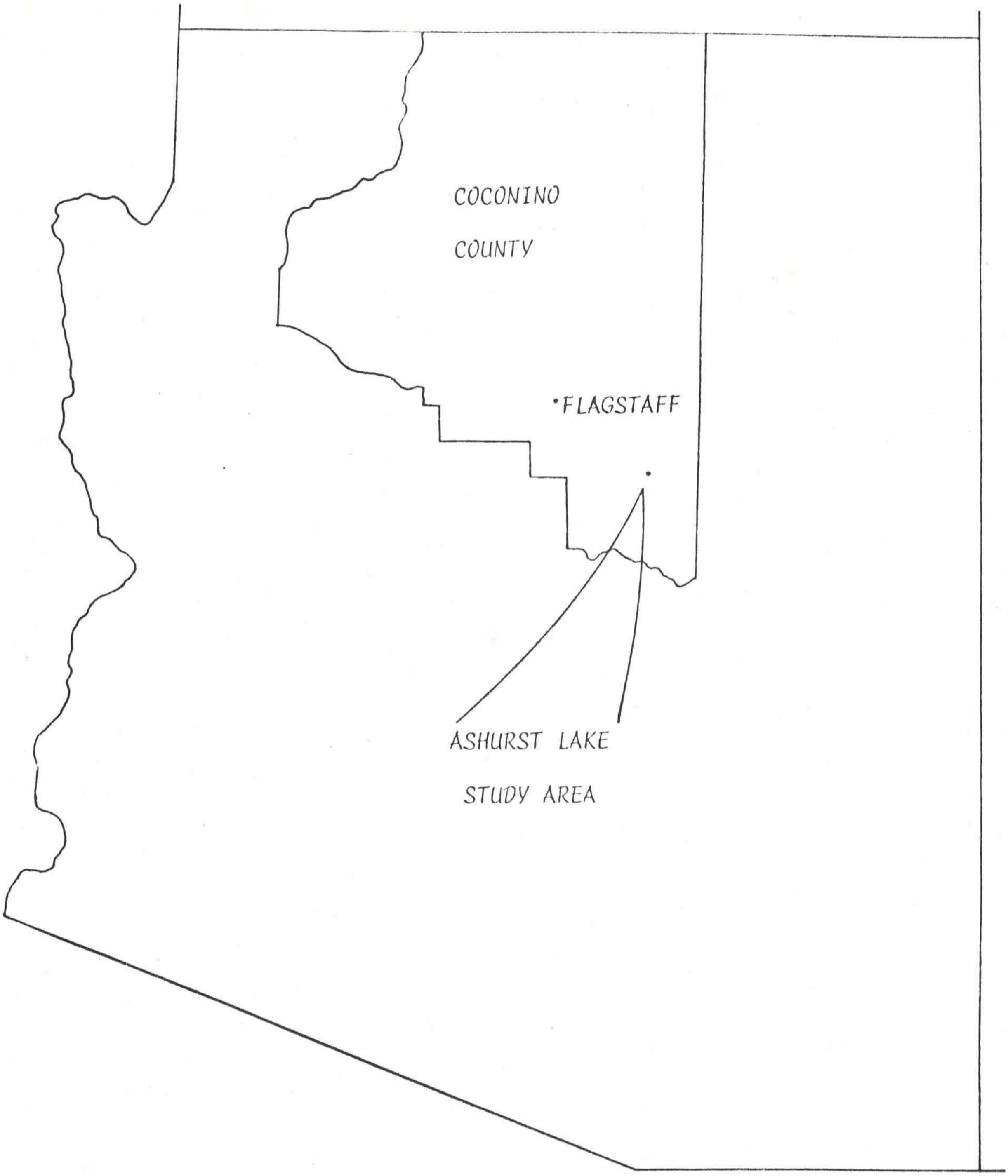


FIGURE 1. LOCATION MAP OF ASHURST LAKE, ARIZONA.

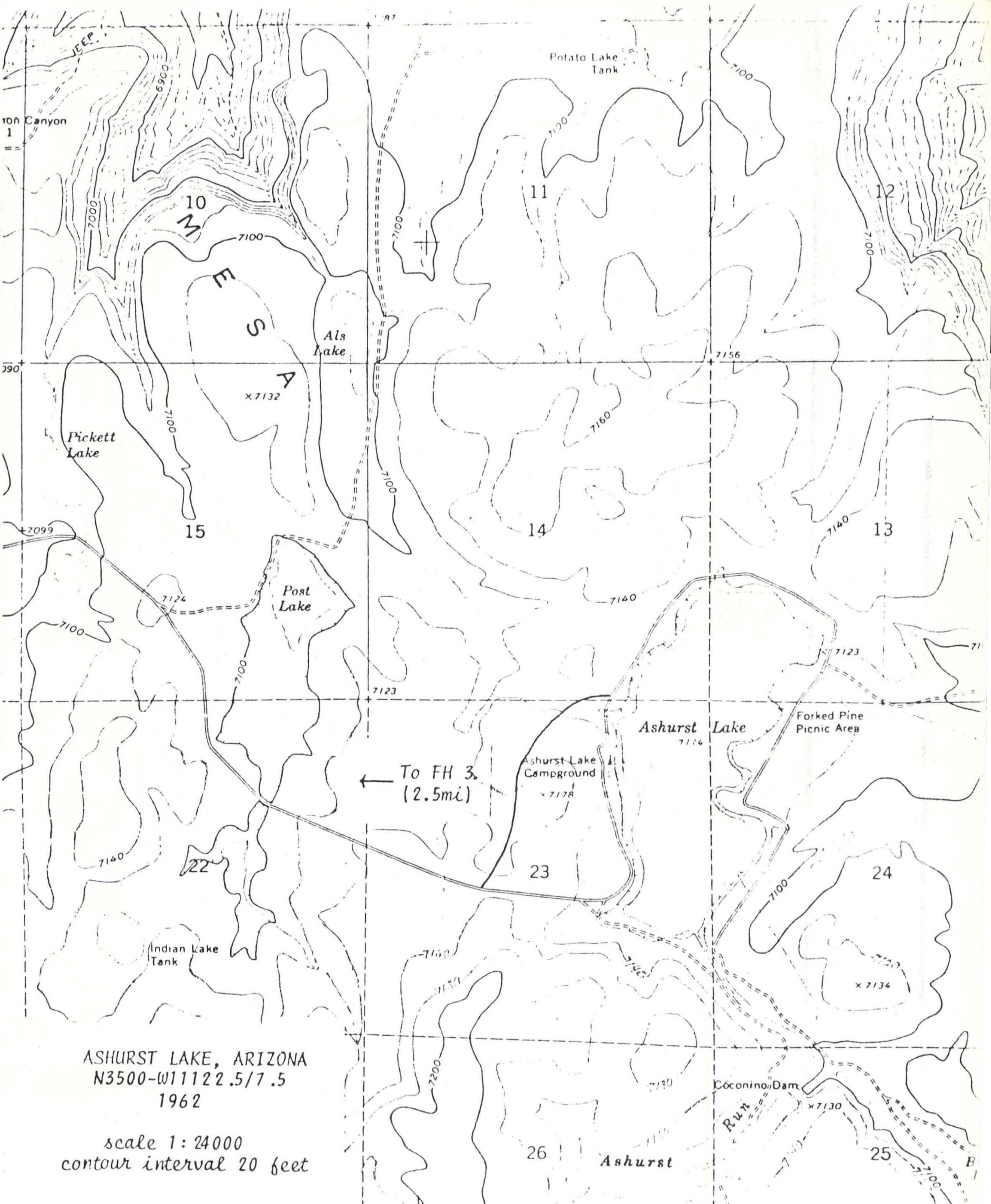


FIGURE 2. REPRODUCTION OF 7.5 MINUTE QUADRANGLE - ASHURST LAKE

(and Walnut Canyon). The mesa is capped by a rather extensive tertiary basalt flow and is directly underlain by the sediments of the Kaibab limestone and the stratigraphic sequence of the Grand Canyon section of the Colorado Plateau. The vegetation of the general area is typical of the Ponderosa pine-Arizona fescue forest, although immediately around the lake itself there apparently have been only a few Ponderosa pines established during the last 100 years, and the immediate site is best described as a pinyon-juniper-Ponderosa pine ecotone.

The Plateau Upland Province, as this region of the state has been designated by the Arizona Water Commission (1975), has a rather distinct climatology in comparison with the rest of Arizona. The high annual precipitation values and long, cold winters of this region result in runoff values which approximate 20% of the gross annual precipitation, an efficiency which is by far the largest for any hydrologic province in the state. The mean snowfall in the region around Ashurst Lake probably ranges between 50 and 75 inches, with the major snowfall events occurring in the January to March period. Although no records are available for confirmation, it is probable that the annual precipitation in the immediate vicinity of Ashurst Lake equals about 15 inches (Beschta, 1976). July and August thunderstorms are usual.

Monthly mean temperatures at this location are probably above 32°F for all months except January. Because of the typically large diurnal temperature range of this province in late winter about 35°F the high daily maximums can translate into occasional early runoff events and these early events, when they do occur, serve to "prime" the soils, so

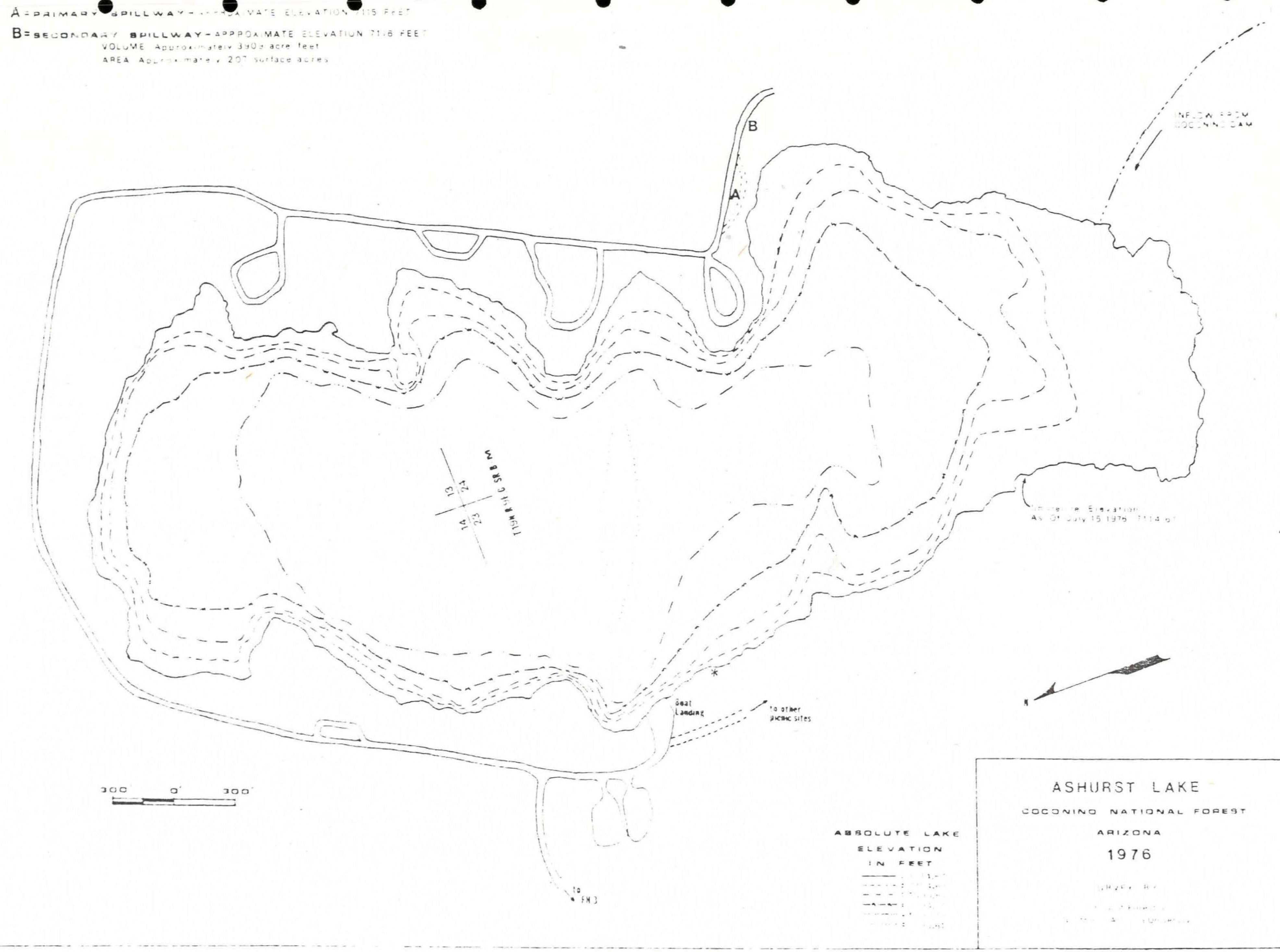


FIGURE 3a MAP OF SHORELINE ELEVATIONS OF ASHURST LAKE AT VARIOUS CAPACITIES.

* LOCATION OF BENCH MARKS SHOWN IN FIGURE 4.

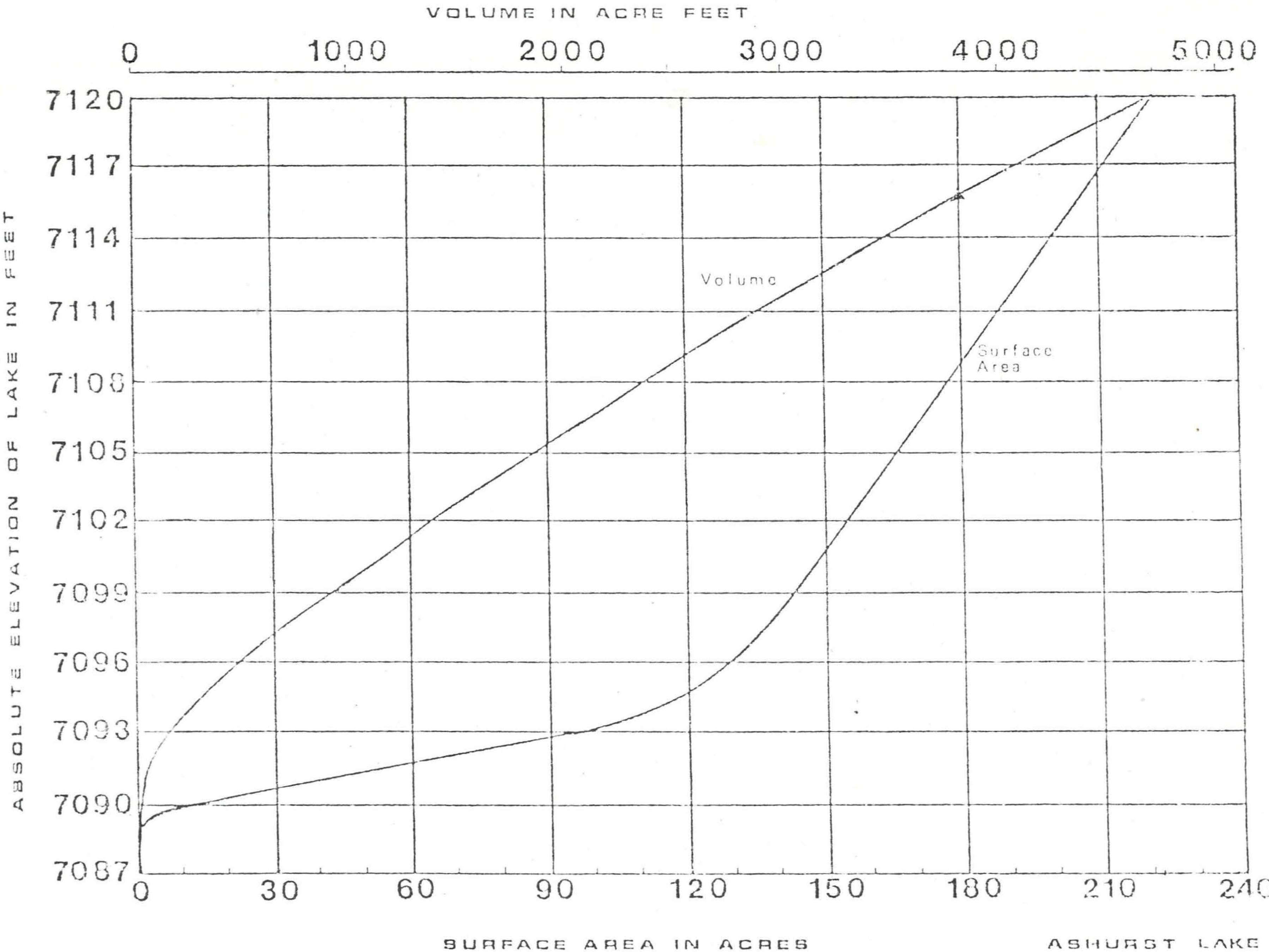


FIGURE 3b. VOLUME AND SURFACE AREA OF ASHURST LAKE v.s. ELEVATION.

that later (March or April) snowmelt can, and sometimes does, act as a rather effective streamflow generator. There is only occasional summer streamflow in this region.

In 1954 the Arizona Game and Fish Department, in cooperation with the U. S. Forest Service, Coconino National Forest, enlarged Ashurst Lake by diking the eastern edge of a natural depression and constructed other facilities to divert spring snowmelt waters from a nearby ephemeral drainage, Ashurst Run, into the now-enlarged impoundment.[1/] Ashurst Lake has subsequently been stocked with trout and has gained in popularity as a recreational fishery. It is considered to be one of the most heavily-fished Arizona lakes on a per-acre basis, and serves as a waterfowl resting area (personal communication, D. Bancroft).

According to a detailed survey of Ashurst Lake completed in 1976, it has a maximum surface elevation of (approximately) 7,116 feet and at that elevation it contains 3,909 acre-feet of water and occupies 207 acres (Figure 3). The lowest point detected in 1976 was 7,089 feet, so the maximum depth of the lake appears to be 26 feet.

Major augmentation to the inflow into Ashurst Lake is designed to result from the diversion of water out of nearby Ashurst Run through a short canal. The outlet control for Ashurst Lake is an undiked portion of the shoreline along the eastern edge of the lake. Seepage losses from the lake are unknown. Since the lake has no perennial inflow or a controllable outlet, surface elevation fluctuations are the combined resultof evaporation, seepage, intermittant surface inflow from the lake's

---

1/The change in elevation of the original lake surface and other details of this project are uncertain.

TABLE ONE

Capacity Table For Ashurst Lake

Stage of Lake in absolute elevation (feet)	Surface Area (acres)	Volume (acre-feet)	Stage of Lake in absolute elevation (feet)	Surface Area (acres)	Volume (acre-feet)
7120.0	222.00	4767.50	7103.0	158.25	1535.38
7119.0	218.25	4547.38	7102.0	154.50	1379.00
7118.0	214.50	4336.00	7101.0	150.75	1226.38
7117.0	210.75	4118.38	7100.0	147.00	1077.50
7116.0[1]	207.00	3909.50	7099.0	143.50	932.25
7115.0[2]	203.25	3704.38	7098.0	139.50	790.75
7114.0	199.50	3503.00	7097.0	135.00	653.50
7113.0	195.75	3305.38	7096.0	130.00	521.00
7112.0	192.00	3111.50	7095.0	123.50	394.25
7111.0	188.25	2921.38	7094.0	112.00	276.50
7110.0	184.50	2735.00	7093.0	96.00	172.50
7109.0	180.75	2552.38	7092.0	68.00	90.50
7108.0	177.00	2373.50	7091.0	41.50	35.75
7107.0	173.25	2198.38	7090.0	13.50	8.25
7106.0	169.50	2027.00	7089.0	1.00	1.00
7105.0	165.75	1859.38	7088.0	0.50	0.25
7104.0	162.00	1695.50	7087.0	0.00	0.00

[1] Approximate elevation of secondary (final) spillway-point B on map (Absolute elevation 7116.01)

[2] Approximate elevation of primary spillway-point A on map (Absolute elevation 7115.07)

rather small watershed and diverted inflow from Ashurst Run.

The watershed of Ashurst Lake proper is only 696 acres: it consists of scattered Ponderosa pines with some pinyon and juniper trees and a rather sparse understory of grass species. Few shrubs are present.

Above Coconino Dam, the Ashurst Run watershed encompasses 6,486 acres, of which the upper (southern) portion is commercial forest. During the study of this watershed 3,060 acres were classified as grassland, 3,394 acres were classified as forested areas (pine-oak or pinyon-juniper), and about 32 acres appeared to be marshland.

METHODOLOGY

The objectives for the study, as listed earlier, were postulated with a view to providing base-line information so that various limnological and hydrological relationships could be established and used in formulating management alternatives for renovating what appears to be a deteriorating fishery. The intent was to draw attention to several aspects of Ashurst Lake, especially to what, if any, differences might exist between it and its principal water source, Coconino Reservoir, as well as to the land use and cover characteristics of each basin.

Specifically, it was proposed to take samples of water from the two subject water bodies, Ashurst Lake and Coconino Reservoir, during the spring and summer of 1978 for physicochemical analysis and to monitor the changes in the surface elevation of Ashurst Lake until 1 October 1978 as well as to measure precipitation during this same period at a point close to the lake. Detailed field examination of the two watersheds was also planned.

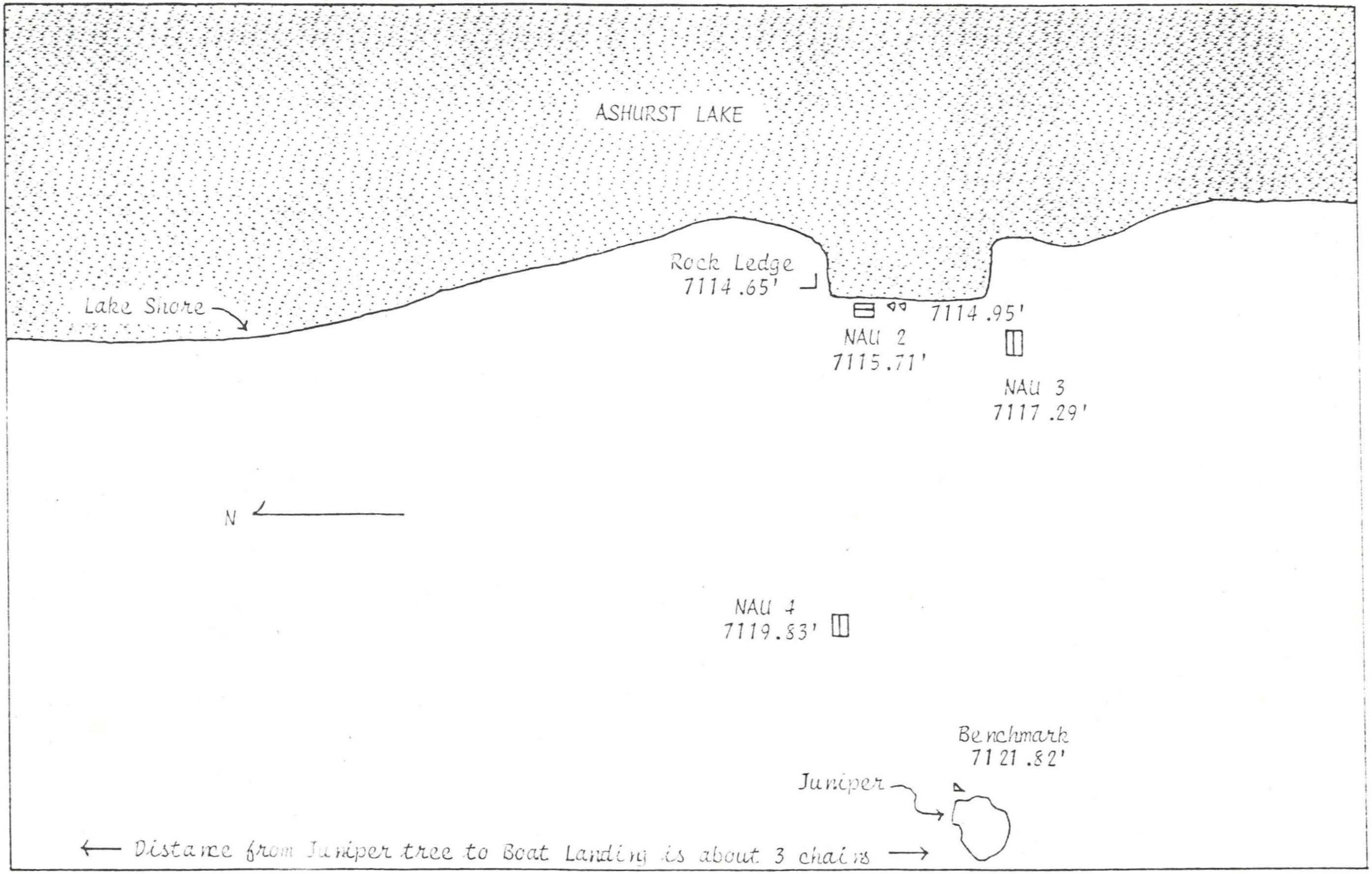


FIGURE 4. MAP OF TEMPORARY BENCH MARKS.

As part of a survey of the lake in 1976 a series of temporary bench marks were located about 200 feet south of the public boat landing on the western edge of the lake. These were later referenced into a "semi-permanent" bench mark (elev. 7121.82) set by a registered professional engineer: this point-of-departure is relatively close (N50 ft.) to the lake shore (Figure 4). Occasional measurements of the lake surface elevation, or stage, during 1977, indicated an elevation of about 7,108 feet on 10 October 1977. The maximum lake level, 7,116 feet was reached by 11 March 1978 as a result of the diversion of snowmelt water from behind Coconino Dam into Ashurst Lake. Based on the stage-volume relationship (Figure 3), it appears that about 1,500 acre feet were added to Ashurst Lake during this diversion, or that its fall 1977 volume was increased by about 163%.

During the course of this investigation the temporary bench marks were used to measure changes in the lake surface elevation (see Appendix One). The U. S. Forest Service-designated "campground host," agreed to maintain a standard (8") raingage near his trailer, about 150 feet south-west of the bench mark location. With his help, observations of rainfall were made from 1 July to 1 October. The lake stage was monitored (almost) weekly, starting on 4 March 1978 and continuing through 7 October 1978.

The scheme for collecting water samples from both Ashurst Lake and Coconino Reservoir for physicochemical analysis was based on providing two levels of sampling intensity. Surface samples from various locations on the perimeter of both lakes were taken seventeen times from 4 March through 10 October 1978. These samples provided a time-intensive data base.

Samples collected on 4 March, 23 May, 7 August and 10 October were also taken at three locations in the middle of Ashurst Lake (Figure 5), and from four depths at each location, 1, 2, 4 and 6 meters. Three replications were taken at each depth for a total of 36 observations on each sampling date from Ashurst Lake for a spatially-intensive sample. Because of the difficulty in transporting a boat to Coconino Reservoir and due to the likelihood of well-mixed water in the small reservoir, samples were taken only from the surface of the reservoir. These samples were collected at locations 1, 2, and 3 (Figure 6). Three replications were taken at each location for a total of nine samples on each of the four dates which were designated to be used for determining the cation content.

Weekly surface samples which were from around the perimeter of Ashurst Lake at locations 5, 6, 7, and 8 (Figure 5) and from locations 1, 2, and 3 on Coconino Reservoir, were used for immediate determinations of pH, DO and EC. No replications were made of these weekly samples.

Immediately following the collection of surface water samples each week, determinations were made of the dissolved oxygen (DO), pH and specific conductance (EC). Duplicate surface samples as well as the mid-lake samples, which were collected on 4 March, 23 May, 7 August and 10 October 1978, were acidified and held in cold storage for later, more extensive, analysis.

DO was read directly from a Yellow Springs model YSI-54 meter which was calibrated at each date against titration (PAO) methodology. The

FIGURE 5. ASHURST LAKE SAMPLING LOCATIONS.

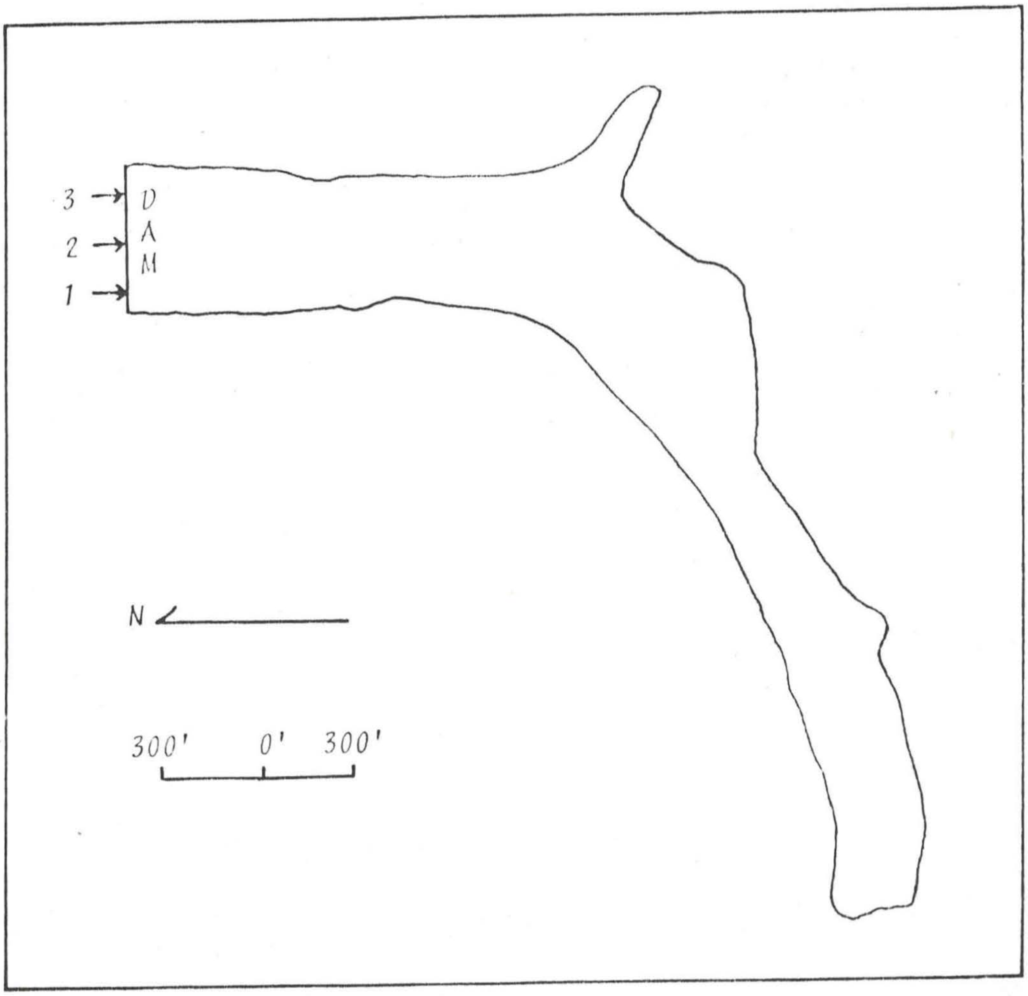


FIGURE 6. COCONINO RESERVOIR SAMPLING LOCATIONS.

Photovolt pH meter was also standardized against a buffer (pH=7.0) solution. A Beckman Solubridge EC meter was employed for specific conductance measurements. At the conclusion of the field data collection period the stored samples were analyzed on a Perkins-Elmer atomic absorbtion spectrophotometer for Ca, Mg, Na, K. Total phosphorus concentrations were determined using a Technieon Autoanalyzer.

The land inventory of the two watersheds behan in July 1978 with a generalized, non-specific sampling to determine if there were any readily-identifiable features, either as land-forms, geologic intrusions or cultural practices, which might explain the difference between the electrical conductivity values for the two water bodies. To accomplish this immediate objective, thirty-six systematically-located plots were established throughout the Ashurst Run watershed and soil type, forage density, slope and apparent livestock utilization were noted at each location.

Four 0.015 acre plots were also systematically located around Ashurst Lake (Figure 7), and an additional eight randomly-located plots were established later in the Ashurst Run watershed (Figure 8). Basal area values were determined wherever there was any overstory. Moreover, whereas the initial survey of 36 locations had been made by using ocular estimating techniques, more precise methods were used for these latter inventories.

RESULTS AND DISCUSSION

The level of Ashurst Lake rose during the Spring 1978 snowmelt season until its capacity was reached, and overflow water may have been returned into Ashurst Run. However, from the 1976 survey (Figure 3), it

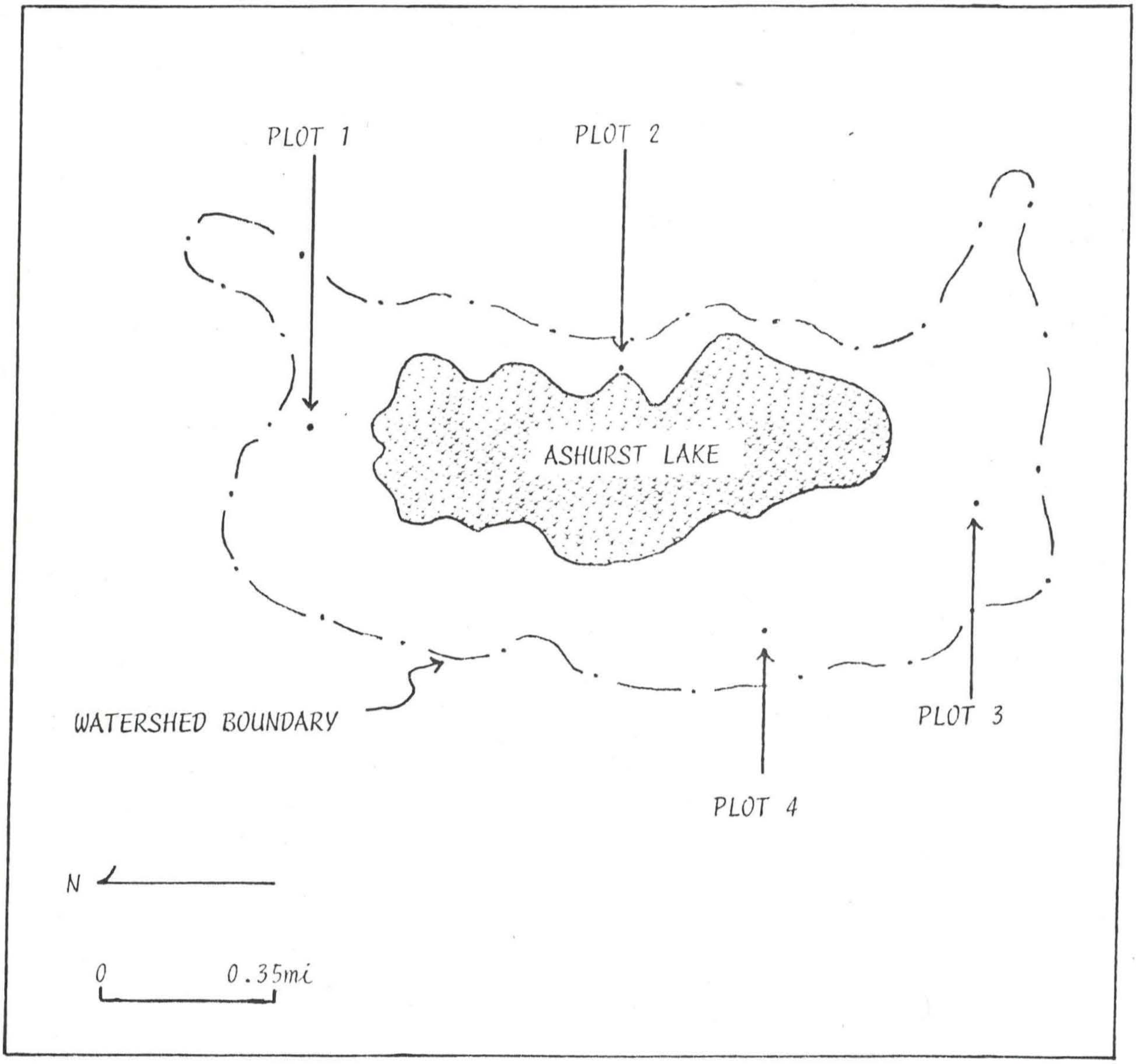


FIGURE 7. LOCATION OF ASHURST WATERSHED INVENTORY PLOTS

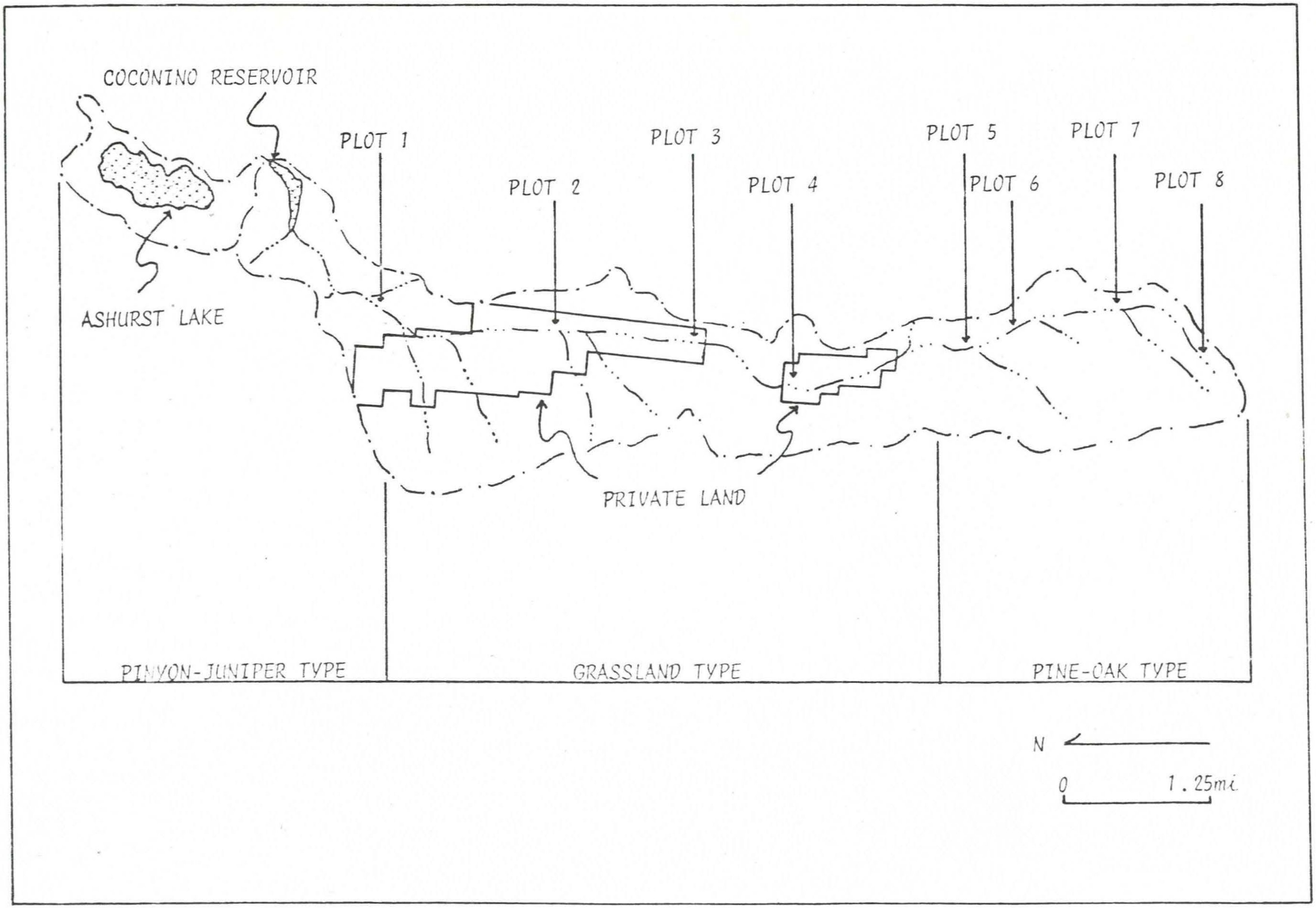


FIGURE 8. TYPE DELINEATIONS AND COCONINO RESERVOIR WATERSHED INVENTORY PLOTS.

appears that the secondary lake control elevation is about 7,116 feet and that a rather extensive overflow pool would have to be filled before water would actually run back into Ashurst Run. Since this diversion of water from Coconino Dam began prior to 11 March 1978, there is no way to verify this quantity of diverted flow, but the lake elevation on 11 March 1978 was determined, using the temporary bench mark system already described, as 7116.08 feet - the maximum recorded. Thereafter it declined (see Table 1) until on 7 October 1978 the elevation was 7111.08, or 5 feet below maximum.

The pattern of this decline is shown in Figure 9. It equals an 1100 acre-feet loss; during this same period accumulated precipitation amounted to 2.75 inches, which over an "average" area of 170 acres would have contributed about 40 acre feet to direct input. The total water loss (about 1140 acre feet) during the summer of 1978 therefore amounted to almost 30% of the lake's volume. If one assumes an "average" surface area of 170 acres and an April-October evaporation loss of 36 inches,[1/] it would appear that only about one-half of the total volume reduction is due to evaporation (510 acre-feet) and that any assumption of insignificant seepage loss is probably invalid. close examination of Figure 9 indicates that after 1 July 1978 the surface water elevation declined almost linearly with time, whereas prior to elevation 7113.4 the decline was inconsistent. Moreover, summer precipitation events appeared to have little effect on lake surface elevation.

It may be that elevation 7113.4 represents some sort of boundary

---

[1/] A value estimated from regional values.

TABLE TWO

Precipitation and Stage Values, 1978

Precipitation Data

Date	Actual (in.)	Accumulated (in.) from 1 July 78
9 July 78	.35"	
15 July 78	.03"	.38"
16 July 78	.25"	.63"
19 July 78	.29"	.92"
24 July 78	.33"	1.25"
25 July 78	.01"	1.26"
1 August 78	.86"	2.12"
2 August 78	.16"	2.28"
10 August 78	.09"	2.37"
12 August 78	.20"	2.57"
21 August 78	.03"	2.60"
31 August 78	.01"	2.61"
1 Sept. 78	.04"	2.65"
21 Sept. 78	.10"	2.75"

Stage Levels

Date	Surface Elevation
4 March 78	7112.37
11 March 78	7116.08
23 May 78	7114.92
2 June 78	7114.62
7 June 78	7114.53
14 June 78	7114.28
23 June 78	7113.79
30 June 78	7113.46
7 July 78	7113.28
13 July 78	7113.13
21 July 78	7112.93
27 July 78	7112.83
1 August 78	7112.72
7 August 78	7112.60
9 August 78	7112.55
11 August 78	7112.53
16 August 78	7112.28
24 August 78	7112.15
30 August 78	7111.92
6 Sept. 78	7111.82
13 Sept. 78	7111.55
21 Sept. 78	7111.50
29 Sept. 78	7111.24
7 Oct. 78	7111.08

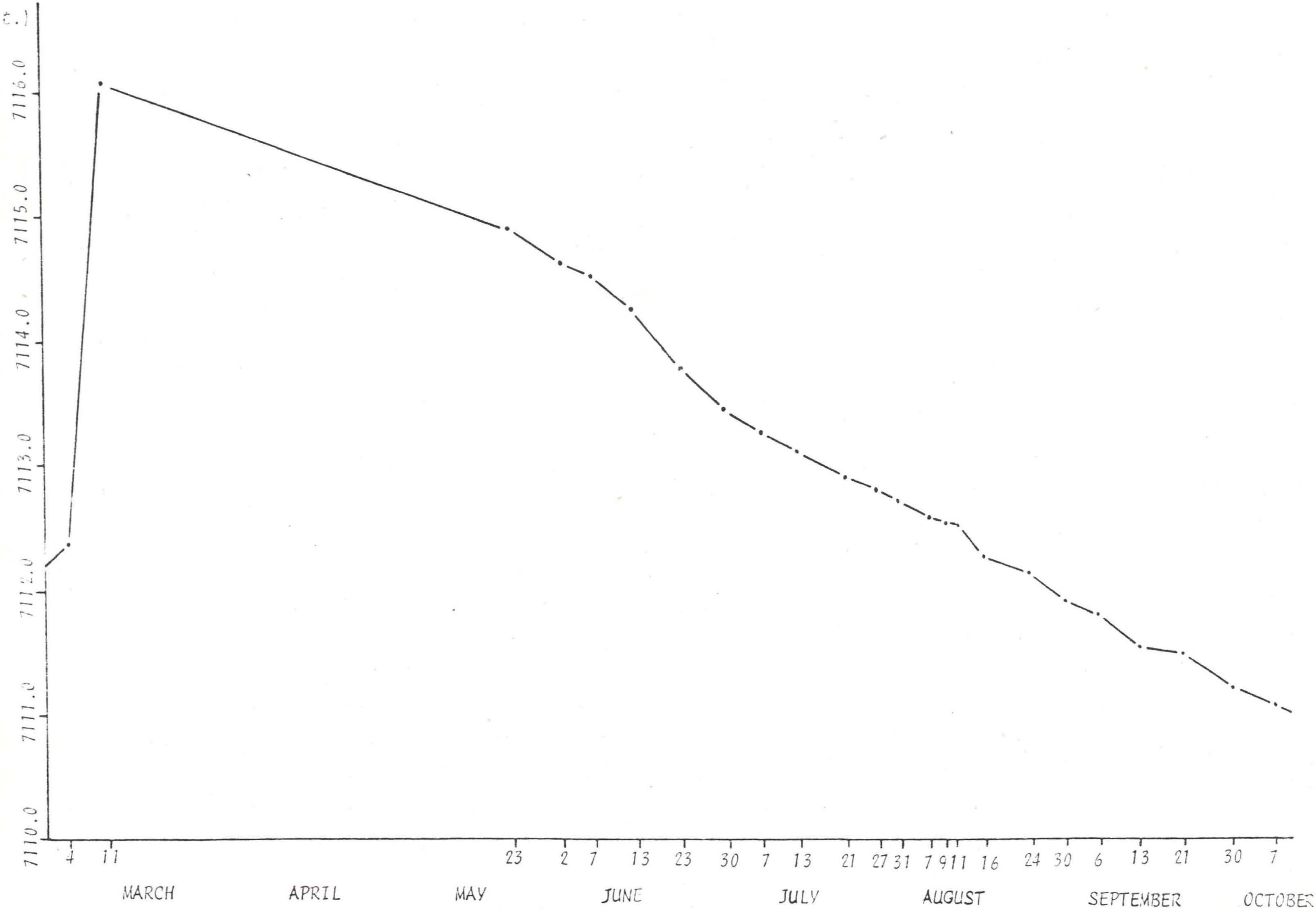


FIGURE 9. CHANGE OVER TIME OF LEVEL OF ASHURST LAKE.

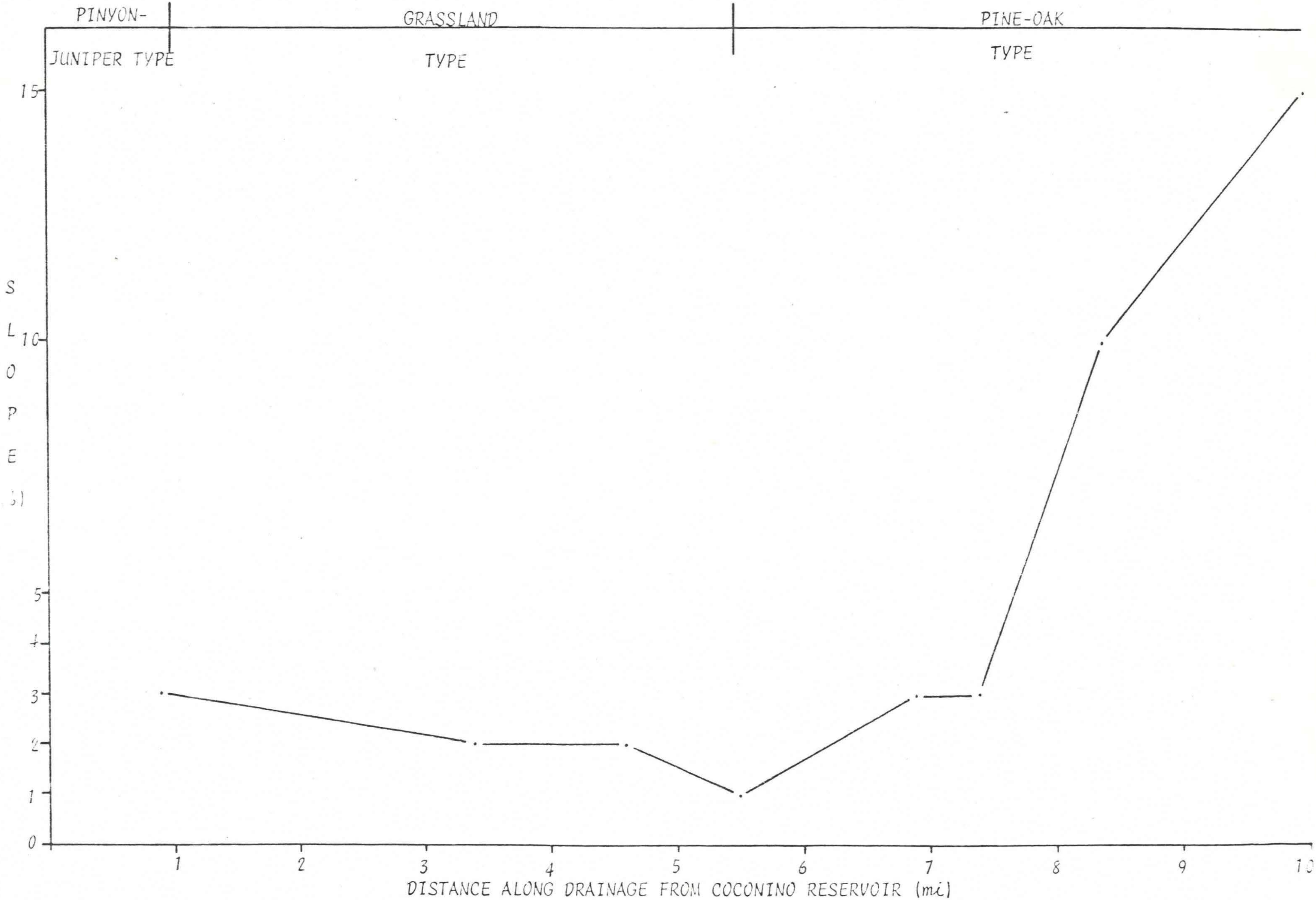


FIGURE 10. SLOPE v.s. DISTANCE FROM COCONINO RESERVOIR.

condition between the original lakeshore surface and the deposited, or diked, material excavated in 1954, and that the loss (evaporation and seepage) rate from 1 July to 7 October 1978 (0.03 inches per day or a total of 30 inches for this period) is realistic. In any case about 1000 acre feet of water (runoff plus diversion) were probably necessary to raise the lake level to its maximum value again in the spring of 1979.

Because of the "closed" nature of Ashurst Lake, which limits any outflow losses except through seepage and evaporation, there is reason to believe that the concentrations of all dissolved materials are increasing, both annually and seasonally, at a faster rate than might be expected for other, "open" lakes in the vicinity such as Lake Mary. The apparent effect of augmenting the lake's contents with (relatively) unloaded water is to dilute the receiving water. The rate at which this dilution occurs depends on two critical factors: the volumetric evaporation loss rate of Ashurst Lake and the mixing rate of both the receiving (or residual) water and the runoff (or diverted) water. No form of a mass balance could be calculated unless the annual diversion flow volume and the actual lake evaporation rate were known, although certainly estimates can be made based on experience and extrapolated values.

It appears that about 20 to 30% of the lake volume is lost to evaporation and seepage each season. Yet because of the low cost of supply augmentation to Ashurst Lake, decreasing this loss is not a management issue; rather the beneficial effects of this annual augmentation on the water quality of the lake bear further investigation.

Analysis of the field data gathered through extensive, and in some areas rather intensive, vegetation and soils inventory procedures

indicates that three vegetation, or habitat, types are present on the study area. The Ashurst Lake watershed is entirely of one type: the Ashurst Run drainage contains ~~are~~ three.

The predominate vegetation around Ashurst Lake is that of the pinyon-juniper type, a very widespread Southwestern community which occurs in the vicinity of this location and is generally found at somewhat lower elevations. There are widely-scattered, old Ponderosa pines throughout this type at this location, suggesting it may be a transition zone. This same community extends up the adjacent Ashurst Run drainage to the south for about 1.6 miles above Coconino Dam. At about this distance the rocky scrubland becomes devoid of the pinyon-juniper overstory and the flat terrain is predominately an improved grassland type for about another 5 miles, or until about 6.5 miles upstream from the dam. Thereafter a well-established Ponderosa pine-Gambel oak community, more typical for this elevation and latitude, predominates; the pine-oak understory is native (Arizona) fescue. This type can be found until the upper end of the watershed is reached, at about 10.5 miles upstream from Coconino Dam.

The soils throughout both watersheds are basalt-derived and, although they might exhibit some localized variations in productivity, they are not nearly as productive as any of the nearby soils which have developed from the (under-lying) Kaibab limestone.

Cobbles and boulders are widespread through the pinyon-juniper and pine-oak communities, but they are relatively few in the grassland type. The pine-oak community, at the south, or upper, end of Ashurst Run is the steepest, while the middle zone, or improved grassland type, is the flatest terrain (Figure 10). Native bunchgrasses are the dominant under-

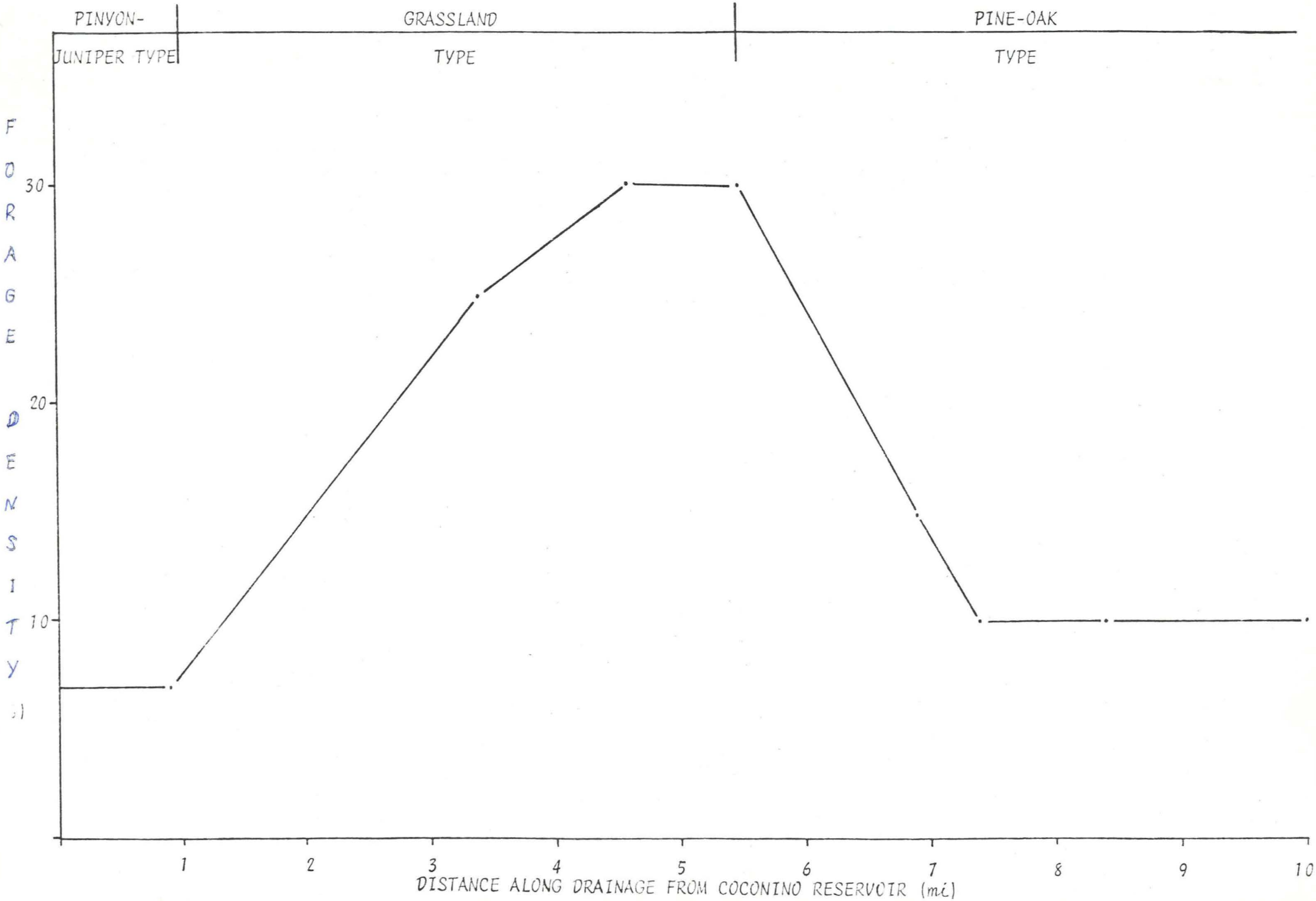


FIGURE 11. FORAGE DENSITY v.s. DISTANCE FROM COCONINO RESERVOIR.

story vegetation in both the pinyon-juniper type and the pine-oak type, while several introduced species are abundant throughout the grassland type, which also has the greatest forage density (Figure 11). Overstory basal area is the greatest in the pine-oak type: there are virtually no trees in the grassland type (Figure 12). Cattle use in 1978 was light throughout the entire study area, although the greatest evidence of cattle use occurred in the grassland type, as might be expected since this land is primarily in private ownership.

Obviously the two contributing areas are different both in aerial extent, topography and vegetation. However, surface water originating from either watershed would probably be very similar in physicochemical characteristics since both watersheds have soils derived from the same parent materials, there is no drastic topographic or climatic change which renders one area distinct from the other (the transitional changes are not abrupt), and the land-use patterns, with the sole exception of the high recreational impact around Ashurst Lake proper, are not very distinctive.

Dissolved oxygen for both Ashurst Lake and Coconino Reservoir were at their highest mean levels on the March 4 sampling date. The values for Ashurst Lake on this date, were D.O.=12.73 mg/l and percent saturation equals 137.4 while Coconino Reservoir's D.O. and percent saturation measured 12.13 mg/l and 122.3 respectively. Ashurst's D.O. dipped to a low of 5.65 mg/l on July 13 with a percent saturation level of 104.75. Coconino Reservoir reached a low in D.O. on the final measurement date, October 10, at 5.37 mg/l with a corresponding percent saturation value of 80.1. Percent saturation was lowest on May 23 in Ashurst Lake (32.2) and

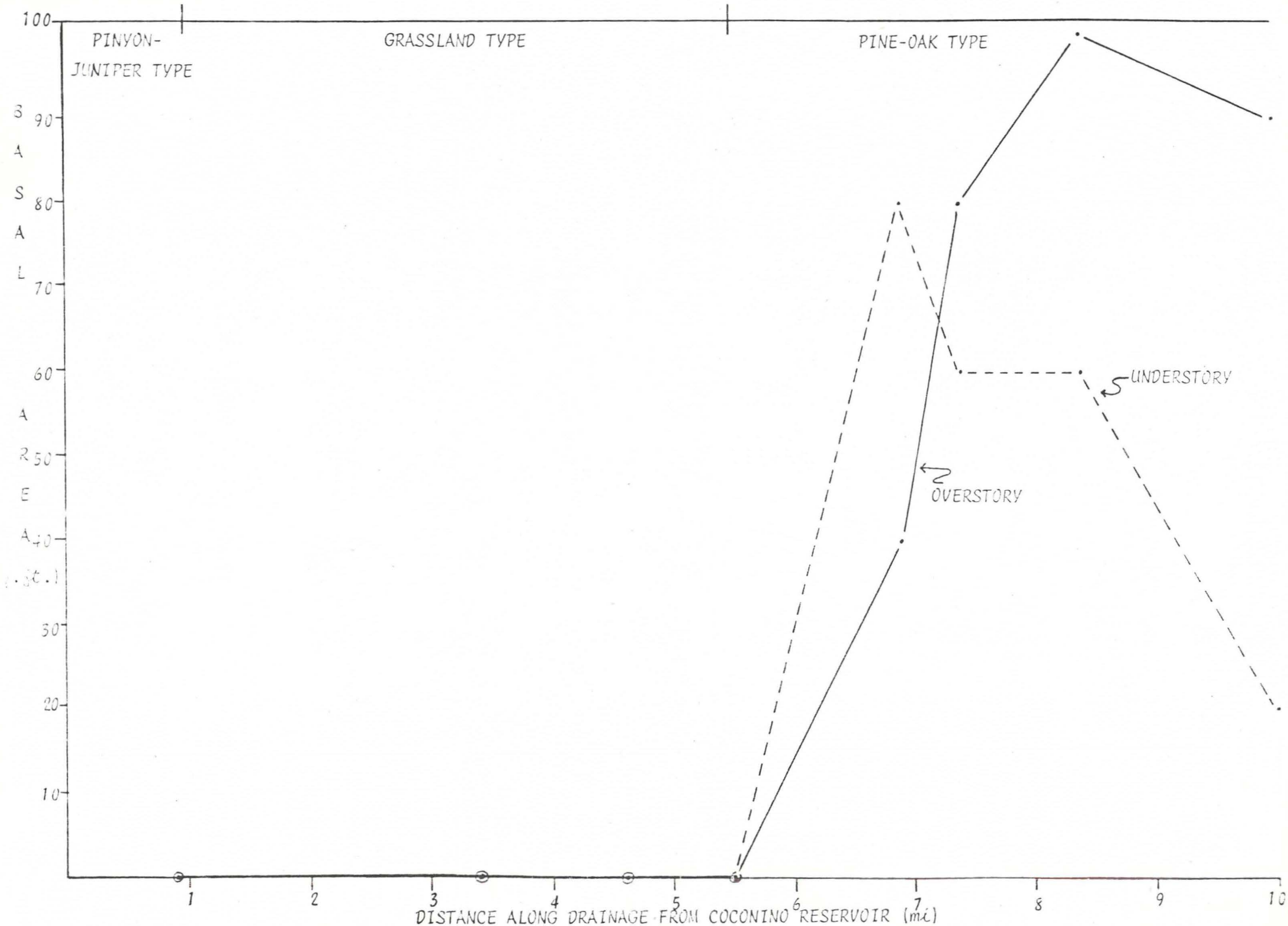


FIGURE 12. BASAL AREA v.s. DISTANCE FROM COCONINO RESERVOIR.

October 10 in Coconino Reservoir (80.1). There was a high correlation between the measured levels D.O. of both bodies of water. A sustained minimum value for D.O. of 6.0 mg/l is generally assumed as a limit for a cold water fishery. (ADHS, 1977)

The highest recorded mean pH value for Ashurst Lake was 9.62 on September 8. Coconino Reservoir's highest mean was 9.97 on August 11. On only one occasion did a sample have a value less than 7.0 in either lake. Throughout the sampling period there was an increasing trend in the pH levels of both lakes with a slight decline at the end. Values were relatively consistent throughout the sampling period. The State of Arizona has set a recommended pH range of 6.5 to 8.6 for waters designated for recreation and aquatic life.

The specific conductance, or electrical conductivity, for these two water bodies showed a wide disparity on March 4: the value for Ashurst was 131.31 mmhos/cm as a mean while the mean Coconino value reading was almost 100 units lower at 35.33 mmhos/cm. Generally, the Ashurst readings showed a decreasing trend over the sampling period while the Coconino Reservoir readings established an increasing trend. The results continuously showed a high disparity between these two lakes, with Ashurst having consistently higher EC values. Since EC is dependent on the total concentration of ionized substances dissolved in the water, it seems apparent that these are distinct water bodies, although Ashurst Lake is not extremely high in ionic content by usual standards.

Calcium levels for both lakes followed the same trend over the sampling period. with the values being low in the early and late spring

and high in the summer and fall. The Ashurst Lake values were consistently higher than those of Coconino Reservoir with the former reaching a peak of 15.74 mg/l on August 7, and the latter exhibiting its highest values on October 10 (mean 11.37 mg/l). There were some considerable disparities in the values obtained from samples taken at different depths, sometimes as much as 10 mg/l.

The magnesium levels for Coconino Reservoir increased and converged throughout the sampling period upon the higher values measured at Ashurst Lake. For the most part individual values obtained from the sampling depths were consistent with little significant variation. The mean values for Ashurst ranged from a high of 2.76 mg/l in March to 2.35 mg/l in May. Coconino however went from a low in March of .863 mg/l to 2.11 mg/l in October.

Potassium levels consistently rose in Coconino Reservoir with the mean values increasing from 2.10 mg/l in March to 5.04 mg/l in October. Ashurst Lake did not establish an obvious trend over this period. Samples collected from the lake in August gave it its highest mean reading of 4.57 mg/l. The standard deviations for the samples taken from both lakes were usually less than 0.5, yet on August 7, a single sample from Ashurst showed 15.32 mg/l and on October 10, a single value from Coconino Reservoir registered 17.85 mg/l. Because of these single values the standard deviations were over 2.0 mg/l.

Ashurst's levels for sodium read consistently higher than those of Coconino. However, the increasing trends extrapolated graphically show a high correlation in seasonal change in these concentrations. Both

lakes experienced a low concentration level in the early and late spring increasing in the summer and peaking in the fall with values of 4.46 mg/l for Ashurst and 3.67 mg/l for Coconino. Standard deviations for sample values were less than 1.0 for both lakes. The highest single value was taken at Coconino on October 10 and was 5.82 mg/l. The analysis for sodium on May 23 was contaminated.

Phosphorus concentrations were not determined for the samples taken on 4 March. It is difficult to know whether or not some seasonal trends occurred in this element's concentration, although concentrations for both lakes had more than doubled by the end of the summer, with Ashurst having its peak mean value in August (0.166 mg/l) and Coconino peaking in October (0.170 mg/l). The mean values for each lake were realistically the same. The highest single reading was obtained from Ashurst on August 7, and was 0.4826 mg/l.

SUMMARY AND CONCLUSIONS

1. Ashurst Lake and Coconino Reservoir were sampled for specific water quality characteristics from March through October 1978 to determine if the water added to Ashurst Lake from Coconino Reservoir might be a possible causal factor in the apparent deterioration of Ashurst Lake as a fishery.

2. No direct evidence was found that the water being diverted into Ashurst Lake was of such a quality that it could be in any way identified as a "polluting water." Nor were the soils, vegetation or land-use patterns distinctly different between the two watersheds.

3. While differences do exist between the receiving water (Ashurst Lake) and the diverted spring run-off water from Ashurst Run, the problems being experienced by Ashurst Lake are probably of localized origin.

4. There is some evidence that the seepage rate of Ashurst Lake is controlled by a contact zone between the original land surface and the earthen dikes constructed in 1954 to raise the lake level.

RECOMMENDATIONS

1. Because of the large investment in recreation improvements already made in Ashurst Lake, it seems reasonable to the author of this report that the current land management plan for the area around this lake include a concentrated effort to forestall its apparent deterioration. (Relocation of capmground sanitory facilities might be one such consideration.)

2. A thorough analysis of the cummulative effect of both grazing and recreation use within the "edge zone" immediately surrounding the lake needs to be made. Undoubtedly some nutrients are being added to the lake ecosystem by these means, but it is unclear just how seriously these activities impact the lake water quality.

3. Minimum hydrologic instrumentation installed at the lake would be of some help in developing a prediction mechanism for forecasting the seasonal variation in the lake elevation and in constructing a salt

and/or nutrient balance for the lake. With regular DO and turbidity determinations and other low-cost measurements a "summer fish kill risk" prediction equation might also be developed. (See: Barica, 1975, as cited by Fisher and Ziebell, 1980.) With such a tool, the Arizona Game and Fish Department could be alerted and effectively use chemical treatments, if warrented.

4. Evidence from research over the past decade indicates strongly that many lakes experiencing relatively rapid eutrophication are the "victims" of past nutrient deposits which are now incorporated in the bottom sediments (Fisher and Ziebell, 1980). This possibility ought to be examined for Ashurst Lake.

5. Until such time as a specific lake management plan is developed, it seems inappropriate to recommend any remedial action. However such a plan, and its supporting studies, should be a priority effort of the management agencies responsible for Ashurst Lake. It does not appear necessary to be concerned about current land use practices on the nearby Ashurst Run watershed in the development of such a plan.

LITERATURE CITED

Arizona Water Commission, 1975, 1977, 1978. Arizona State Water Plan. (3 phases: 3 reports). Phoenix: Arizona Water Commission.

Barica, J., 1975. Summerkill Risk in Prarie Ponds and Possibilities of its Prediction. Journal of the Fisheries Research Board of Canada. 32(1) 283-288.

Beschta, R. L., 1976. Climatology of the Ponderosa Pine Type in Arizona. University of Arizona, Agricultural Experimental Station Technical Bulletin 228.

Fisher, C. J. and C. D. Ziebell, 1980. Effects of Watershed Use on Water Quality and Fisheries in an Arizona Mountain Lake. Bulletin No. 7, Eisenhower Consortium for Western Environmental Forestry Research.

Schwartz, S., 1976. Responses of Physio-chemical Parameters and Plankton Population to Treatment with Aquazine at Ashurst Lake, Arizona. M.S. Thesis (unpubl.) Northern Arizona University, Flagstaff, Arizona, August 1976.

LOCATION DETAILS FOR TEMPORARY BENCH MARKS

The temporary bench marks were referenced to the permanent bench mark of 7121.82 feet elevation by using a dumpy level and a graduated rod. The approximate locations of these marks are shown by Figure 4. NAU 4 is marked by a white box divided by a red line painted on a northeast facing rock approximately 20 feet at N65E of the 7121.82 feet mark. The elevation of the red line of NAU 4 is 7119.83 feet. NAU 3 is also marked by a white box divided by a red line, and is located on a north facing rock approximately 34 feet at S50E of NAU 4. The elevation of the red line of NAU 3 is 7117.29 feet. NAU 2 is marked with a box similar to that of NAU 3 and NAU 4, and is located on an east facing rock approximately 15 feet at N16°E of NAU 3. Its elevation is 7115.71 feet. Two small red triangles are painted on the same rock as NAU 2. The base of each triangle is at 7114.95 feet and they are located approximately 12.5 feet at N18E of NAU 3. Another temporary bench mark is a rock ledge designated by an "L" painted on a south facing rock approximately 5 feet at N32E from NAU 2. The elevation of this ledge is 7114.65 feet.

WATER QUALITY DATA

Appendix 2.a.

Sample Designation Scheme

Summary Data

2.a.1. Summary and Run Data values for DO, pH and EC

2.a.2. Summary and Run Data values for Ca, Mg, K, Na and P

Appendix 2.b.

Graphical Display of
Selected Water Quality Parameters versus Time

Appendix 2.c.

Statistical Analysis of Water Quality Data

Appendix 2.a.

SAMPLE DESIGNATION SCHEME USED FOR BASIC DATA

Ex: "A112"

First Digit

A = Ashurst Lake

B = Coconino Reservoir

Secon Digit

Location Code: depth at which sample taken

1 = surface
2 = 1m below surface
3 = 2m below surface
4 = 4m below surface

Fourth Digit

Replicate Code (Max. = 3)

SUMMARY DATA

DATE	SOURCE	PARAMETER	DO mg/1	pH –	EC mmhos/cm
3/4	Ashurst	$\bar{x}$	12.73	8.25	131.31
		s	1.99	.087	3.17
	Coconino	$\bar{x}$	12.13	7.13	35.33
		s	.416	.152	.577
5/23	Ashurst	$\bar{x}$	6.42	7.54	120.44
		s	.248	.146	1.12
	Coconino	$\bar{x}$	6.59	7.47	62.33
		s	.257	.050	1.00
6/7	Ashurst	$\bar{x}$	7.20	8.03	115.83
		s	.060	.065	.389
	Coconino	$\bar{x}$	7.39	7.62	68.33
		s	.078	.097	1.94
6/14	Ashurst	$\bar{x}$	7.16	7.92	112.33
		s	.079	.062	.651
	Coconino	$\bar{x}$	7.48	7.65	67.66
		s	.120	.053	.707
6/23	Ashurst	$\bar{x}$	6.02	7.92	115.75
		s	.298	.359	1.50
	Coconino	$\bar{x}$	6.00	7.30	68.33
		s	.264	.173	7.64
6/30	Ashurst	$\bar{x}$	6.52	8.18	118.50
		s	.125	.221	.577
	Coconino	$\bar{x}$	6.87	7.87	79.33
		s	.057	.251	3.51
7/7	Ashurst	$\bar{x}$	6.25	8.28	123.50
		s	.129	.150	1.29
	Coconino	$\bar{x}$	6.33	7.97	85.67
		s	.115	.057	2.89
7/13	Ashurst	$\bar{x}$	5.65	8.35	123.50
		s	.100	.100	1.00
	Coconino	$\bar{x}$	6.07	8.43	82.67
		s	.057	.115	3.78
7/21	Ashurst	$\bar{x}$	6.75	8.21	116.75
		s	.208	.165	3.95
	Coconino	$\bar{x}$	6.80	8.53	84.00
		s	.608	.378	2.64

DATE	SOURCE	PARAMETER	DO mg/1	pH -	EC mmhos/cm
7/27	Ashurst	$\bar{x}$	7.50	8.95	124.00
		s	.365	.191	.816
	Coconino	$\bar{x}$	7.90	9.40	90.67
		s	.458	.173	5.51
8/7	Ashurst	$\bar{x}$	6.82	9.38	122.04
		s	1.27	.382	4.18
	Coconino	$\bar{x}$	6.28	9.51	76.22
		s	.272	.116	1.48
8/11	Ashurst	$\bar{x}$	6.86	7.75	136.00
		s	.298	2.13	12.73
	Coconino	$\bar{x}$	8.47	9.97	87.33
		s	.115	.057	2.52
8/19	Ashurst	$\bar{x}$	6.68	9.28	100.50
		s	.377	.206	4.20
	Coconino	$\bar{x}$	6.43	9.17	65.00
		s	.251	.152	15.00
9/8	Ashurst	$\bar{x}$	7.58	9.62	120.25
		s	1.17	.262	2.22
	Coconino	$\bar{x}$	6.47	9.20	81.00
		s	.251	0.00	3.61
9/13	Ashurst	$\bar{x}$	6.85	9.42	125.25
		s	.238	.050	.927
	Coconino	$\bar{x}$	6.83	9.00	87.00
		s	.057	.100	1.73
9/21	Ashurst	$\bar{x}$	7.78	9.50	115.75
		s	.525	.081	2.06
	Coconino	$\bar{x}$	7.67	8.60	83.00
		s	.057	.173	0.00
10/10	Ashurst	$\bar{x}$	5.78	9.03	111.73
		s	1.20	.255	4.07
	Coconino	$\bar{x}$	5.37	7.51	86.78
		s	.223	.214	3.07

RAW DATA

DATE	SAMPLE	DO mg/1	% SAT. -	pH -	EC mmhos/cm
3/4	A111	10.8	157	8.3	138
	112	12.7	157	8.3	138
	113	12.6	155	8.3	135
	121	13.8	140	8.3	130
	122	17.8	190	8.3	128
	123	13.5	165	8.2	132
	131	13.2	135	8.2	130
	132	14.0	170	8.3	135
	133	14.8	179	8.2	132
	141	11.2	113	8.2	138
	142	13.7	168	8.2	130
	143	9.8	121	8.3	130
	A311	11.8	115	8.1	138
	312	11.2	136	8.3	132
	313	12.3	149	8.4	130
	321	12.0	118	8.3	135
	322	11.2	136	8.2	130
	323	13.0	160	8.3	130
	331	11.8	118	8.2	132
	332	18.8	197	8.3	130
	333	12.0	147	8.2	130
	341	12.5	125	8.1	130
	342	15.2	186	8.2	130
	343	11.4	138	8.3	130
	A411	14.2	139	8.0	130
	412	14.1	172	8.3	130
	413	9.3	115	8.4	128
	421	10.9	107	8.1	135
	422	11.7	141	8.2	130
	423	13.7	126	8.3	125
	431	11.3	111	8.2	130
	432	13.6	165	8.3	130
	433	10.3	127	8.3	128
	441	11.6	113	8.3	130
	442	15.1	183	8.3	128
	443	11.5	139	8.4	130
	B11	12.0	121	7.0	35
	21	11.8	119	7.1	35
	31	12.6	127	7.3	36

DATE	SAMPLE	DO mg/1	% SAT. -	pH -	EC mmhos/cm
5/23	A111	6.2	81	7.6	120
	112	6.5	83	7.7	122
	113	6.6	81	7.3	123
	121	6.2	81	7.6	120
	122	6.5	83	7.7	122
	123	6.6	85	7.3	123
	131	6.4	82	7.4	122
	132	6.4	82	7.7	119
	133	6.1	78	7.6	120
	141	7.0	87	7.7	120
	142	6.2	81	7.6	120
	143	6.1	78	7.7	120
	151	6.7	86	7.3	118
	152	6.9	88	7.15	120
	153	6.5	83	7.7	120
	A311	6.9	88	7.6	120
	312	6.2	81	7.7	119
	313	6.4	82	7.7	120
	321	6.7	86	7.4	120
	322	6.2	81	7.6	120
	323	6.5	83	7.6	122
	331	6.5	83	7.4	122
	332	6.2	81	7.3	120
	333	6.2	81	7.6	120
	341	6.5	83	7.4	123
	342	6.4	82	7.5	120
	343	6.6	85	7.6	122
	351	7.2	92	7.4	120
	352	6.4	82	7.6	119
	353	6.2	81	7.7	120
	A411	6.3	81	7.6	120
	412	6.4	82	7.6	120
	413	6.3	81	7.7	120
	421	6.4	79	7.6	121
	422	6.6	81	7.4	122
	423	6.6	81	7.5	121
	431	6.2	81	7.6	120
	432	6.2	81	7.6	120
	433	6.2	81	7.6	120
	441	6.2	79	7.7	120

DATE	SAMPLE	DO mg/1	% SAT. -	pH -	EC mmhos/cm
5/23	A442	6.3	81	7.6	120
	443	6.4	82	7.4	120
	451	6.1	78	7.3	120
	452	6.4	82	7.7	120
	453	6.3	81	7.5	120
	B111	6.5	92	7.5	62
	112	6.5	92	7.5	62
	113	6.4	91	7.5	62
	211	6.7	95	7.5	62
	212	6.6	94	7.5	62
	213	6.8	96	7.4	62
	311	6.7	95	7.4	62
	312	6.1	86	7.5	62
	313	7.0	99	7.4	65
6/2	A511	1/	1/	7.9	1/
	521			7.9	
	611			8.1	
	621			8.1	
	711			8.2	
	721			8.2	
	811			8.3	
	B111			7.8	
	211			8.1	
	311			7.9	
6/7	A511	7.1	105	8.1	116
	512	7.2	108	8.1	116
	513	7.2	107	8.1	116
	611	7.1	107	8.0	116
	612	7.2	108	8.0	116
	613	7.2	108	8.1	116
	711	7.2	107	8.1	116
	712	7.3	108	7.9	115
	713	7.3	108	8.0	115
	811	7.2	107	8.0	116
	812	7.2	108	8.0	116
	813	7.2	107	8.0	116

1/
Instruments inoperative

DATE	SAMPLE	DO mg/1	% SAT. -	pH -	EC mmhos/cm
6/7	B111	7.5	108	7.6	70
	112	7.3	107	7.6	70
	113	7.5	109	7.4	70
	211	7.3	107	7.7	68
	212	7.4	107	7.6	69
	213	7.4	108	7.6	67
	311	7.4	107	7.7	64
	312	7.4	107	7.7	69
	313	7.3	105	7.7	68
6/14	A511	7.1	109	7.9	113
	512	7.1	109	7.9	112
	513	7.1	109	7.8	112
	611	7.1	109	7.9	113
	612	7.1	109	7.9	113
	613	7.1	108	7.9	113
	711	7.3	113	8.0	112
	712	7.2	111	7.9	111
	713	7.3	113	7.9	112
	811	7.2	111	8.0	112
	812	7.2	109	8.0	112
	813	7.1	109	8.0	113
	B111	7.5	113	7.7	68
	112	7.3	112	7.7	67
	113	7.5	114	7.7	68
	211	7.3	112	7.6	68
	212	7.6	116	7.6	67
	213	7.6	113	7.7	67
	311	7.4	111	7.7	67
	312	7.5	113	7.6	68
	313	7.6	114	7.6	69
6/23	A511	6.1	98	7.6	118
	611	6.3	103	7.7	115
	711	5.6	96	8.4	115
	811	6.1	101	8.0	115
	B111	5.7	104	7.5	60
	211	6.2	124	7.2	70
	311	6.1	105	7.2	75

DATE	SAMPLE	DO mg/l	% SAT. -	pH -	EC mmhos/cm
6/30	A511	6.5	99	8.0	119
	611	6.4	98	8.1	119
	711	6.7	101	8.5	118
	811	6.5	100	8.1	118
	B111	6.9	105	7.9	76
	211	6.8	104	8.1	83
	311	6.9	105	7.6	79
7/7	A511	6.2	91	8.1	122
	611	6.3	90	8.2	124
	711	6.4	92	8.4	125
	811	6.1	88	8.4	123
	B111	6.4	91	8.0	89
	211	6.4	92	8.0	84
	311	6.2	90	7.9	84
7/13	A511	5.6	87	8.3	125
	611	5.6	87	8.3	123
	711	5.8	90	8.5	123
	811	5.6	87	8.3	123
	B111	6.1	94	8.3	87
	211	6.1	94	8.5	81
	311	6.0	93	8.5	80
7/21	A511	6.7	109	8.2	120
	611	6.8	108	8.1	115
	711	7.0	114	8.45	120
	811	6.5	104	8.1	112
	B111	6.1	99	8.1	81
	211	7.1	113	8.7	85
	311	7.2	118	8.8	86
7/27	A511	7.1	108	8.8	125
	611	7.9	122	9.0	123
	711	7.3	111	8.8	124
	811	7.7	117	9.2	124

DATE	SAMPLE	DO mg/1	% SAT. -	pH -	EC mmhos/cm
7/27	B111	8.4	129	9.6	96
	211	7.8	120	9.3	91
	311	7.5	114	9.3	85
8/7	A111	7.9	120	9.7	125
	112	8.1	124	9.7	124
	113	7.7	120	9.6	122
	121	7.7	117	9.6	122
	122	7.8	118	9.6	127
	123	7.8	121	9.7	121
	131	7.2	109	9.5	121
	132	7.2	108	9.6	121
	133	7.2	109	9.5	119
	141	6.9	107	9.3	118
	142	6.8	101	9.3	119
	143	6.9	104	9.5	121
	151	2.9	44	8.3	121
	152	6.3	96	9.1	119
	153	6.1	92	9.0	114
	A311	7.8	120	9.7	124
	312	7.5	117	9.5	121
	313	8.1	124	9.8	123
	321	8.0	125	9.8	127
	322	8.1	124	9.7	122
	323	7.9	121	9.7	122
	331	7.6	118	9.6	124
	332	7.6	117	9.6	121
	333	6.4	98	9.7	120
	341	6.7	100	9.4	120
	342	6.8	104	9.5	121
	343	6.7	101	9.4	120
	351	5.8	88	9.1	121
	352	4.8	74	8.7	112
	353	4.9	75	8.7	115
	A411	8.0	126	9.8	127
	412	8.1	125	9.8	126
	413	8.1	127	9.7	128
	421	7.5	117	9.6	135
	422	7.5	117	9.8	127
	423	7.9	124	9.6	130

DATE	SAMPLE	DO mg/1	% SAT. -	pH -	EC mmhos/cm
8/7	A431	6.4	99	9.3	128
	432	6.4	100	9.3	125
	433	6.7	101	9.2	121
	441	6.1	92	9.1	120
	442	6.0	91	9.0	120
	443	6.0	91	8.8	119
	451	2.8	44	8.6	118
	452	5.0	79	8.8	120
	453	5.3	82	8.8	121
	B111	6.4	103	9.6	76
	112	6.1	96	9.4	75
	113	6.1	96	9.4	76
	211	6.4	101	9.6	75
	212	6.6	103	9.7	77
	213	6.7	108	9.6	75
	311	6.3	100	9.5	75
	312	6.0	95	9.4	78
	313	5.9	94	9.4	79
8/11	A511	7.0	108	9.6	125
	611	7.2	109	9.5	125
	711	6.8	104	6.5	146
	811	6.5	98	5.4	148
	B111	8.6	130	10.0	90
	211	8.4	126	10.0	85
	311	8.4	127	9.9	87
8/19	A511	7.0	104	9.3	105
	611	7.0	104	9.5	102
	711	6.4	95	9.0	100
	811	6.3	94	9.3	95
	B111	6.2	95	9.2	80
	211	6.4	96	9.3	65
	311	6.7	100	9.0	50
9/8	A511	6.4	98	9.4	119
	611	7.3	109	9.6	121
	711	7.4	113	9.5	118
	811	9.2	140	10.0	123

DATE	SAMPLE	DO mg/1	% SAT. -	pH -	EC mmhos/cm
9/8	B111	6.7	101	9.2	85
	211	6.5	98	9.2	80
	311	6.2	96	9.2	78
9/13	A511	6.6	94	9.4	125
	611	7.0	98	9.4	126
	711	7.1	101	9.4	124
	811	6.7	95	9.5	126
	B111	6.9	98	8.9	86
	211	6.8	96	9.0	89
	311	6.8	96	9.1	86
9/21	A511	8.5	124	9.6	113
	611	7.3	100	9.4	116
	711	7.8	108	9.5	118
	811	7.5	104	9.5	116
	B111	7.7	107	8.4	83
	211	7.7	107	8.7	83
	311	7.6	105	8.7	83
10/10	A111	6.3	87	9.2	113
	112	6.4	92	9.2	115
	113	6.5	97	9.2	103
	121	6.5	94	9.2	110
	122	6.4	95	9.2	109
	123	6.4	96	9.2	100
	131	6.4	91	9.1	115
	132	6.4	95	9.3	110
	133	6.6	94	9.1	107
	141	5.8	81	9.1	117
	142	5.9	82	9.1	111
	143	6.0	87	8.7	107
	151	3.6	51	8.6	112
	152	3.0	42	8.7	110
	153	3.4	47	8.7	115
	A311	6.6	90	9.1	110
	312	6.6	95	9.3	111
	313	6.8	95	9.0	116
	321	6.7	94	9.2	110

DATE	SAMPLE	DO mg/1	% SAT. -	pH -	EC mmhos/cm
10/10	A322	6.4	96	9.2	105
	323	6.5	90	9.0	117
	331	6.2	85	9.2	116
	332	6.2	87	9.1	110
	333	6.0	86	9.2	105
	341	5.9	86	9.2	113
	342	6.2	87	9.0	111
	343	5.8	86	9.2	111
	351	3.6	51	8.8	117
	352	3.6	50	8.5	111
	353	4.1	57	8.6	112
	A411	7.2	100	9.2	111
	412	7.1	96	9.4	117
	413	7.3	101	9.3	114
	421	6.6	91	9.3	113
	422	6.5	95	9.0	118
	423	6.6	97	9.2	115
	431	6.4	91	9.1	110
	432	6.2	86	9.2	113
	433	6.2	91	9.2	111
	441	5.5	82	9.0	111
	442	5.6	82	9.1	114
	443	5.5	78	8.8	111
	451	3.1	43	8.6	112
	452	3.8	52	8.5	108
	453	3.7	51	8.4	121
	B111	5.8	87	7.4	85
	112	5.1	75	8.0	80
	113	5.3	79	7.5	85
	211	5.2	78	7.7	89
	212	5.2	78	7.3	90
	213	5.2	78	7.4	89
	311	5.5	82	7.5	88
	312	5.5	82	7.4	87
	313	5.5	82	7.4	88

SUMMARY DATA

DATE	SOURCE	PARAMETER	Ca mg/1	Mg mg/1	K mg/1	Na mg/1	P mg/1
3/4	Ashurst	$\bar{x}$	5.32	2.76	2.95	1.91	1/
		s	1.49	.402	.423	.327	
	Coconino	$\bar{x}$	1.54	.863	2.10	.711	
		s	0	0	0	0	
5/23	Ashurst	$\bar{x}$	4.42	2.35	2.73	1.61	.053
		s	.530	.290	.250	.910	.003
	Coconino	$\bar{x}$	2.74	1.59	2.61	.96	.069
		s	.910	.420	.160	.400	.002
8/7	Ashurst	$\bar{x}$	15.74	2.66	4.57	3.66	.166
		s	2.97	.641	3.16	.257	.133
	Coconino	$\bar{x}$	11.13	1.86	3.30	2.28	.145
		s	.523	.197	.421	.909	.072
10/10	Ashurst	$\bar{x}$	14.76	2.55	3.28	4.46	.163
		s	1.05	.338	.278	.829	.098
	Coconino	$\bar{x}$	11.37	2.11	5.04	3.67	.170
		s	.337	.240	2.47	1.86	.022

1/ No reliable data

RAW DATA

DATE	SAMPLE [1]	Ca mg/1	Mg mg/1	K mg/1	Na mg/1	P mg/1
3/4	A11	9.57	2.65	3.64	2.78	[3]
	12	5.79	3.68	2.82	2.26	
	13	4.27	2.47	2.72	1.95	
	14	4.99	2.45	3.01	1.83	
	31	5.96	2.75	3.30	1.86	
	32	4.75	3.41	3.16	1.86	
	33	5.88	2.79	3.35	1.83	
	34	5.15	2.51	3.12	1.77	
	41	4.43	2.42	3.01	1.89	
	42	4.59	2.41	2.48	1.69	
	43	3.79	2.68	2.04	1.66	
	44	4.67	2.87	2.82	1.52	
	B11	1.54	.863	2.10	.711	
5/23	A11	5.63	2.51	2.53	2.01	
	12	4.27	2.46	2.96	1.49	
	13	4.51	2.64	2.77	1.46	
	14	3.63	2.29	2.92	1.51	
	15	4.91	2.14	2.68	1.46	
	31	4.83	2.72	2.96	1.49	
	32	4.43	2.72	2.68	4.79	
	33	4.35	1.84	2.20	1.20	
	34	3.38	2.43	3.06	1.17	
	35	4.67	2.03	2.48	1.20	
	41	4.19	2.58	2.63	1.43	
	42	4.67	1.92	3.01	1.20	
	43	3.95	2.01	2.39	1.46	
	44	4.35	2.57	2.77	.998	
	45	4.67	2.45	2.96	1.28	
	B11	2.58	1.61	2.72	.712	
	21	2.42	1.25	2.77	.682	
	31	2.10	1.63	2.63	.595	
5/23 [2]	A11	3.48	1.98	[3]	[3]	.0504
	12	3.67	1.35			.0588
	13	3.42	1.73			.0563
	14	3.41	1.64			.0555
	15	3.42	1.59			.0555

[1] Simple designation described on first page of this section of appendix

[2] Duplicate analysis

[3] Samples contaminated: no reliable values available

DATE	SAMPLE	Ca mg/1	Mg mg/1	K mg/1	Na mg/1	P mg/1
5/23	A31	2.65	1.52	2/	2/	.0563
	32	3.28	1.96			.0579
	33	2.52	1.57			.0465
	34	3.19	1.64			.0491
	35	3.25	1.73			.0517
	41	3.96	1.86			.0517
	42	3.96	1.76			.0526
	43	3.92	1.75			.0509
	44	3.82	2.09			.0535
	45	3.99	2.05			.0553
8/7	A11	15.39	2.59	15.32 1/	3.53	.0483
	12	14.22	2.74	3.47	3.49	.0649
	13	15.54	2.66	4.30	4.29	.0570
	14	14.83	1.91	4.85	4.00	.0500
	15	- 2/	-	-	3.38	.2119
	31	14.70	2.66	3.64	3.64	.0485
	32	14.69	2.61	3.51	3.78	.0306
	33	14.01	2.62	3.37	3.71	.1446
	34	14.08	2.18	3.34	3.60	.0478
	35	20.12	3.39	4.23	3.56	.3522
	41	13.93	2.41	3.65	3.38	.0590
	42	14.69	2.37	3.67	3.64	.0470
	43	14.57	2.50	3.31	3.53	.0455
	44	14.97	2.04	2.41	3.38	.0530
	45	24.97	4.52	4.88	3.96	.4826
	B11	11.73	1.73	3.65	3.31	.2278
	21	10.89	1.77	2.83	1.60	.1139
	31	10.77	2.09	3.41	1.92	.0939
10/10	A11	14.77	2.80	3.02	3.64	.1244
	12	15.50	2.43	3.11	3.64	.1339
	13	15.25	2.35	3.23	3.85	.1339
	14	14.70	2.67	2.86	4.58	.0926
	15	16.21	3.19	3.00	3.64	.3919
	31	14.38	2.58	3.33	3.45	.0949
	32	15.20	2.35	3.47	3.67	.0971
	33	14.72	2.83	3.54	5.09	.2081
	34	15.26	2.07	3.23	5.05	.1485
	35	12.04	3.01	3.37	4.14	.3316
	41	15.40	2.24	3.98	6.07	.1163

1/ Suspect data: not included in statistical analysis

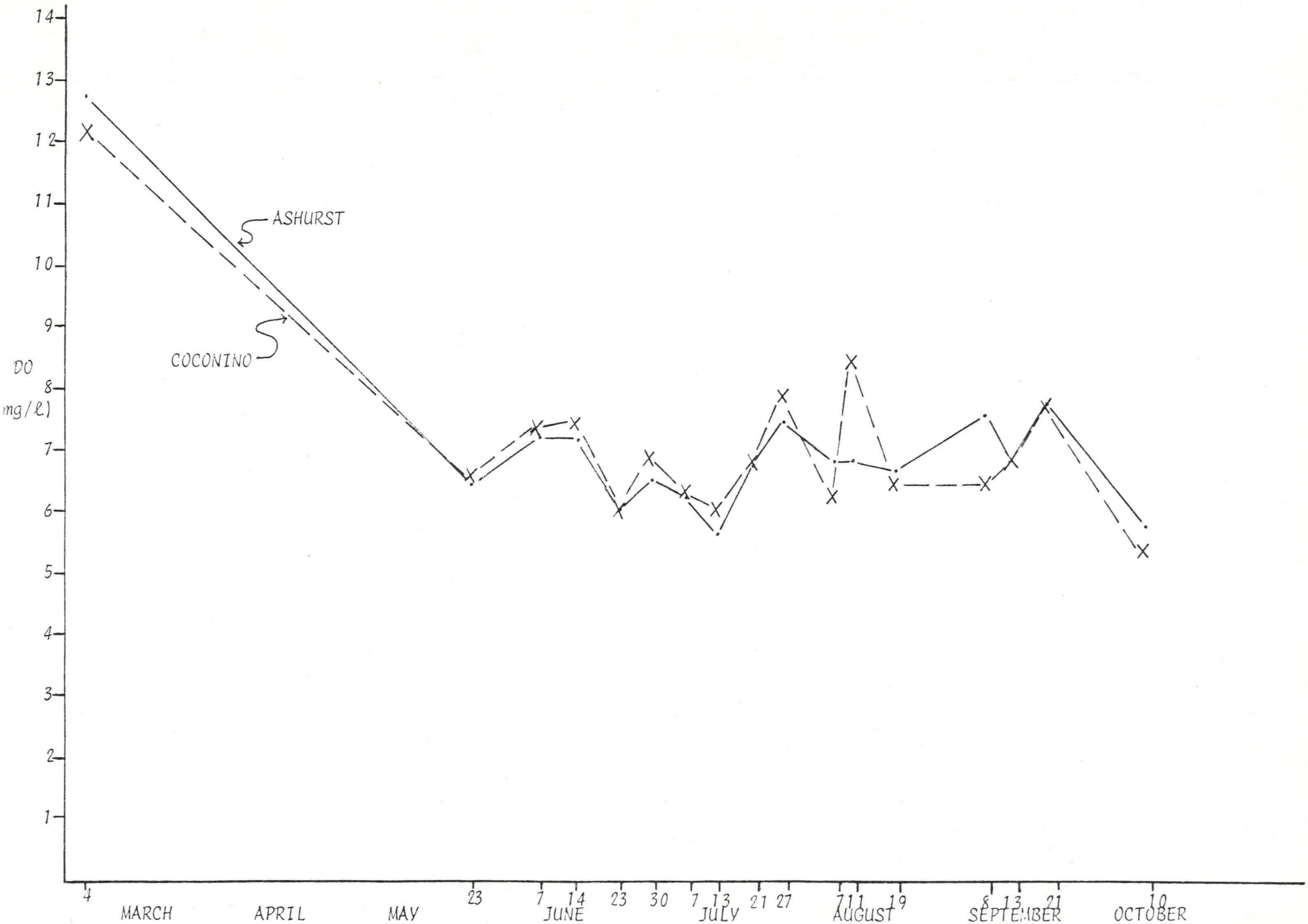
2/ Samples contaminated: no reliable values available

DATE	SAMPLE	Ca mg/1	Mg mg/1	K mg/1	Na mg/1	P mg/1
10/10	A42	13.56	2.31	3.51	5.05	.0824
	43	14.39	2.54	3.08	5.78	.0824
	44	13.99	2.03	3.11	4.58	.1154
	45	16.13	2.83	3.36	4.65	.2949
	B11	11.73	2.26	7.89 [1/]	5.82	.1507
	21	11.33	2.23	3.68	2.73	.1669
	31	11.06	1.83	3.54	2.47	.1949

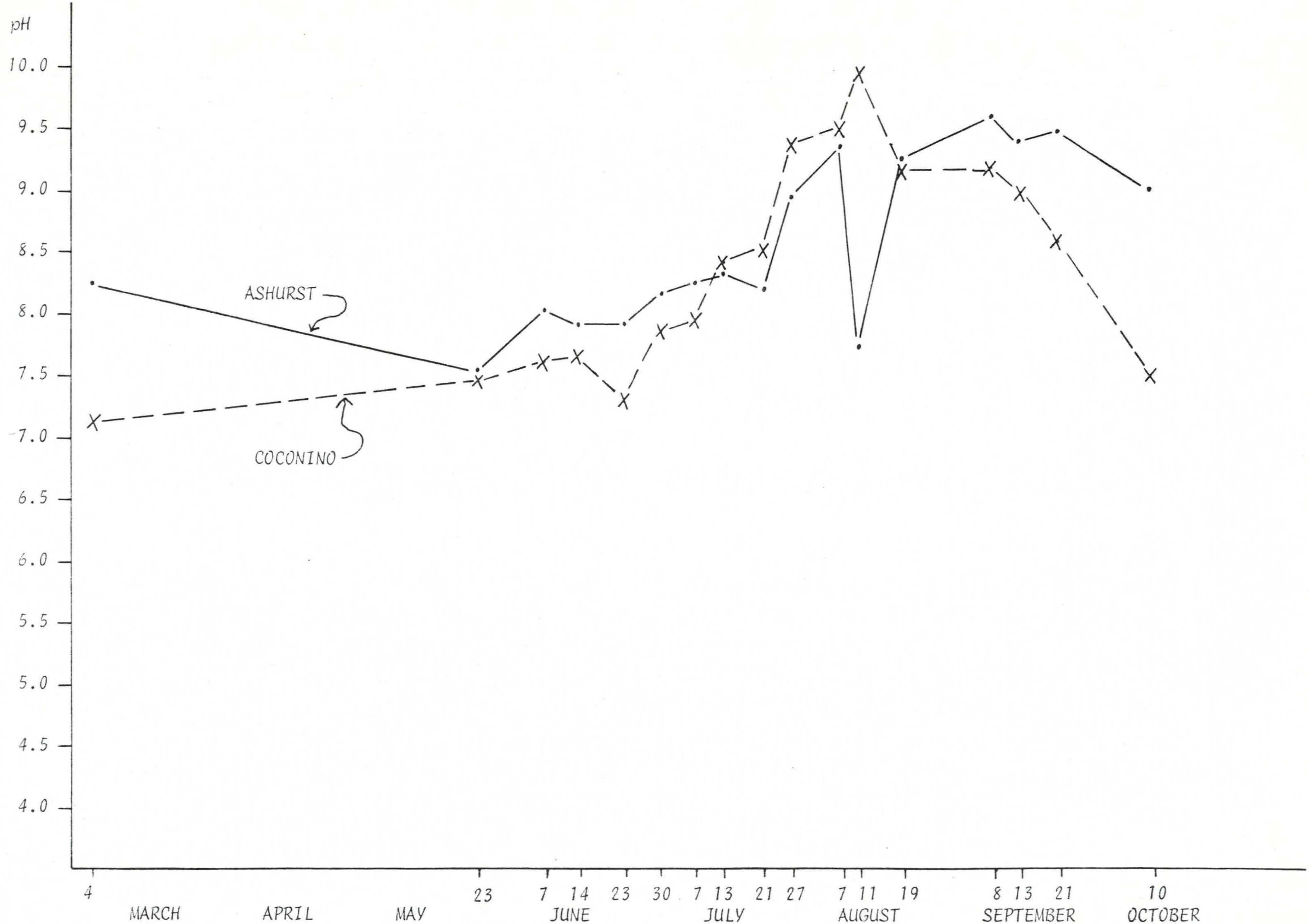
[1/] Suspect data: not included in statistical analysis.

GRAPHICAL DISPLAY OF WATER QUALITY

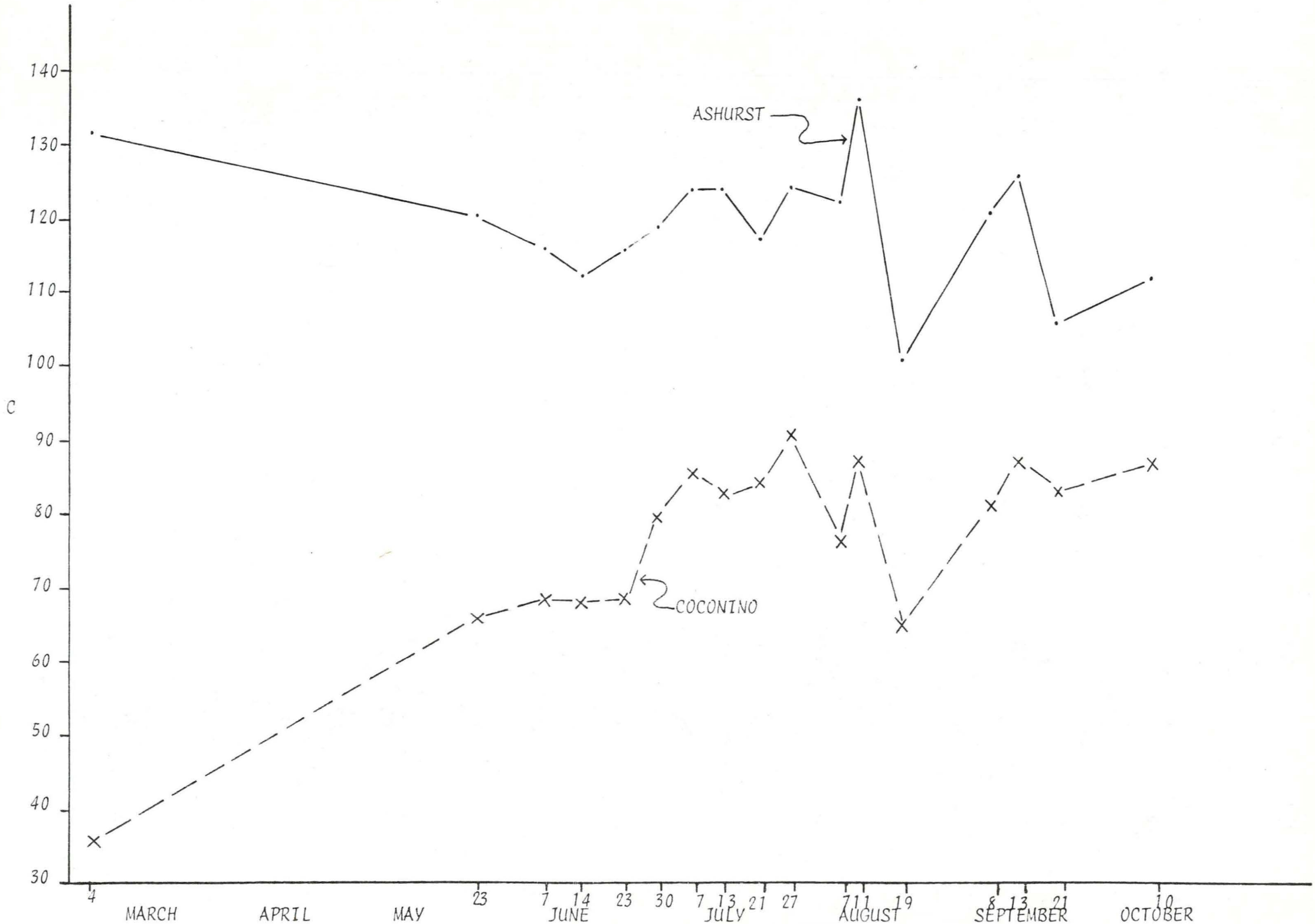
Parameters versus Time



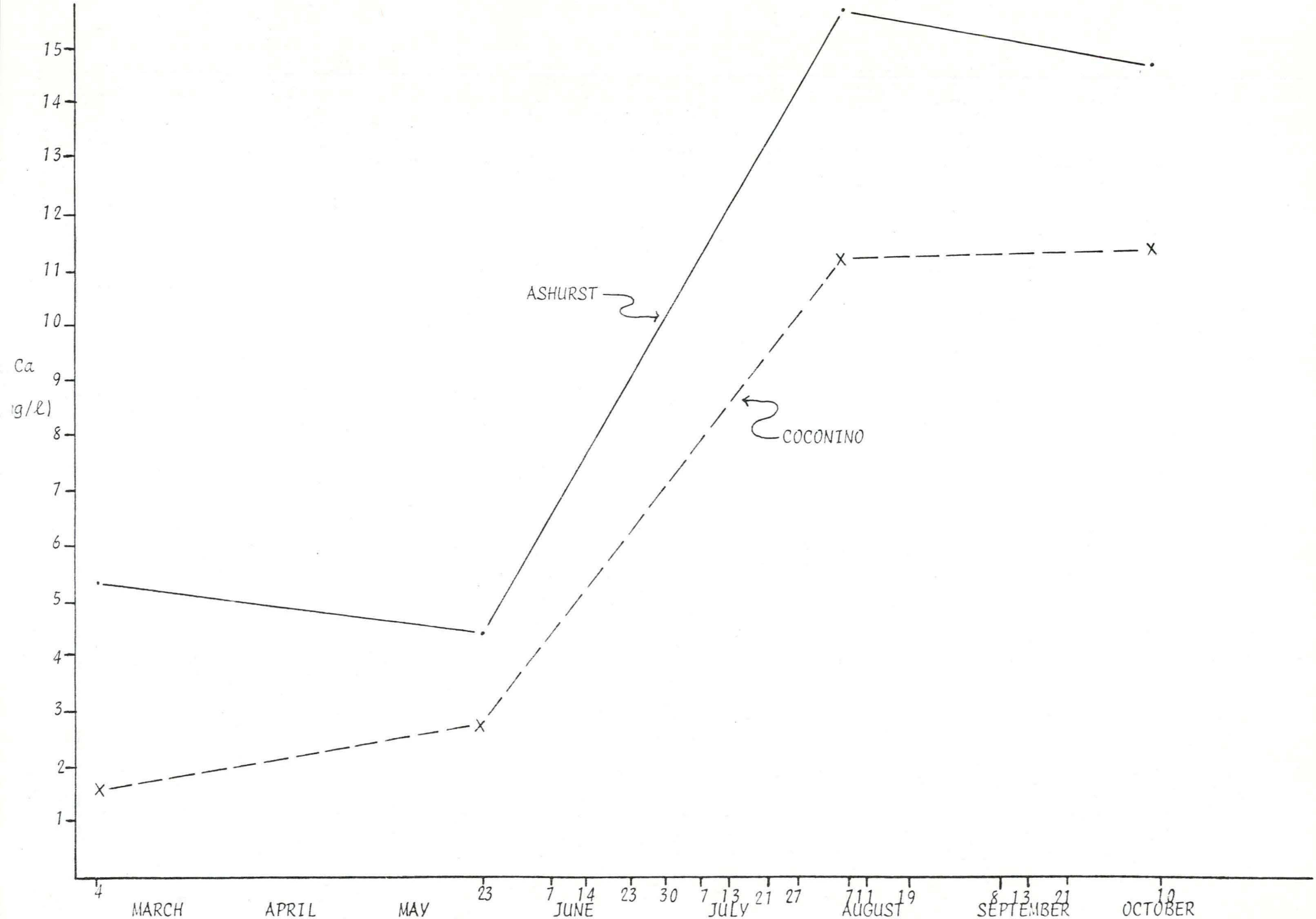
CHANGE IN MEAN DO OVER TIME



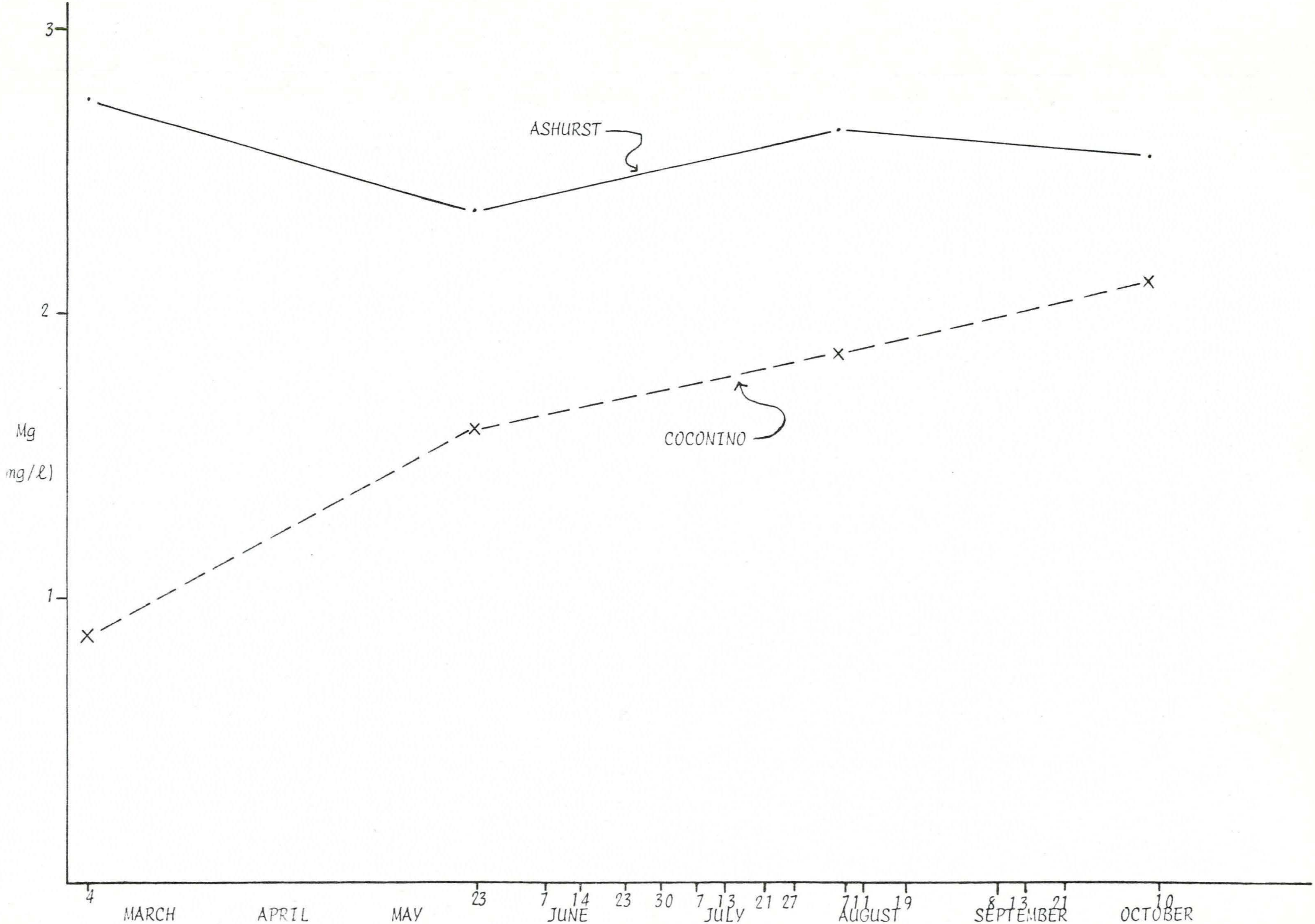
CHANGE IN MEAN pH OVER TIME



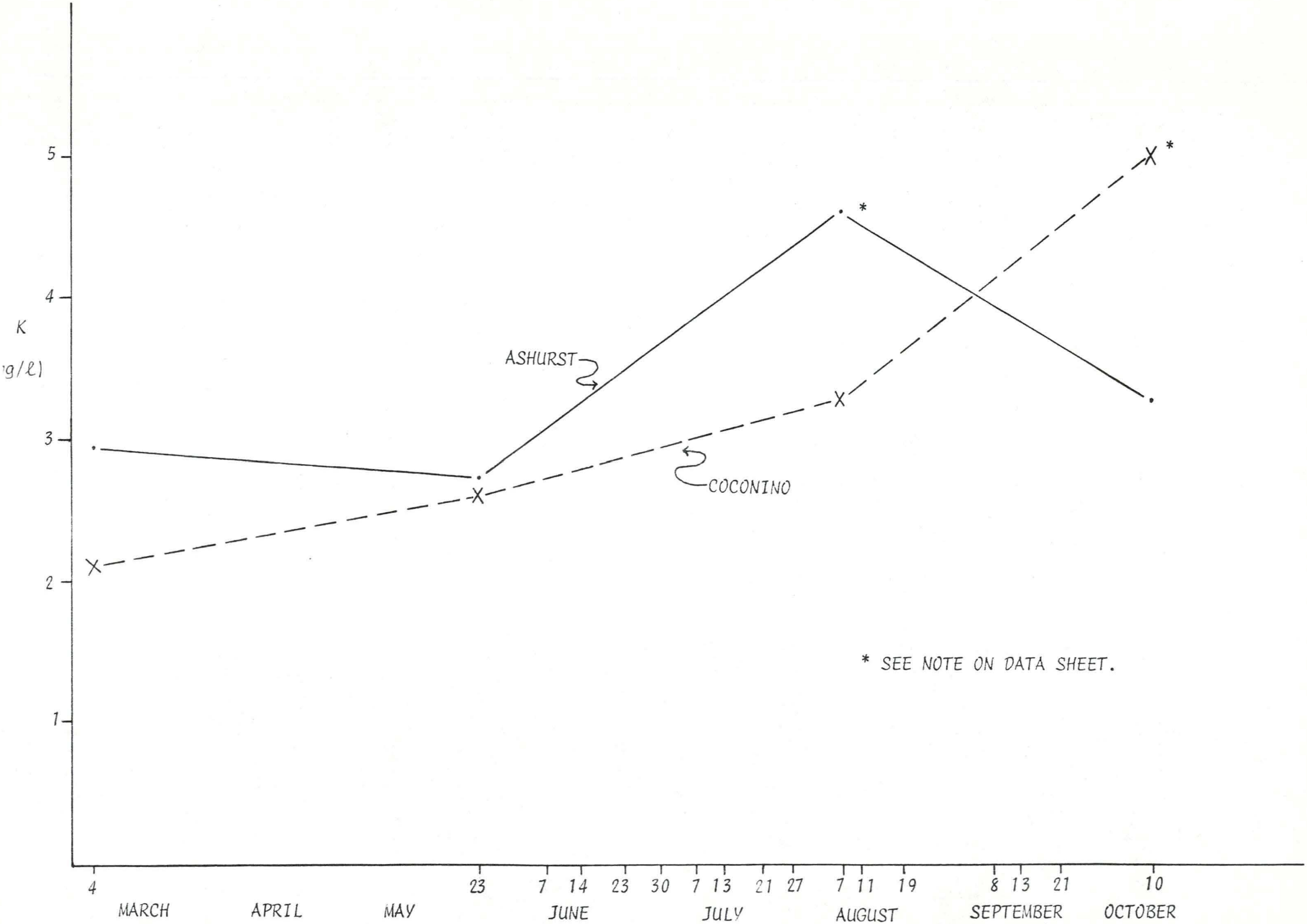
CHANGE IN MEAN EC OVER TIME



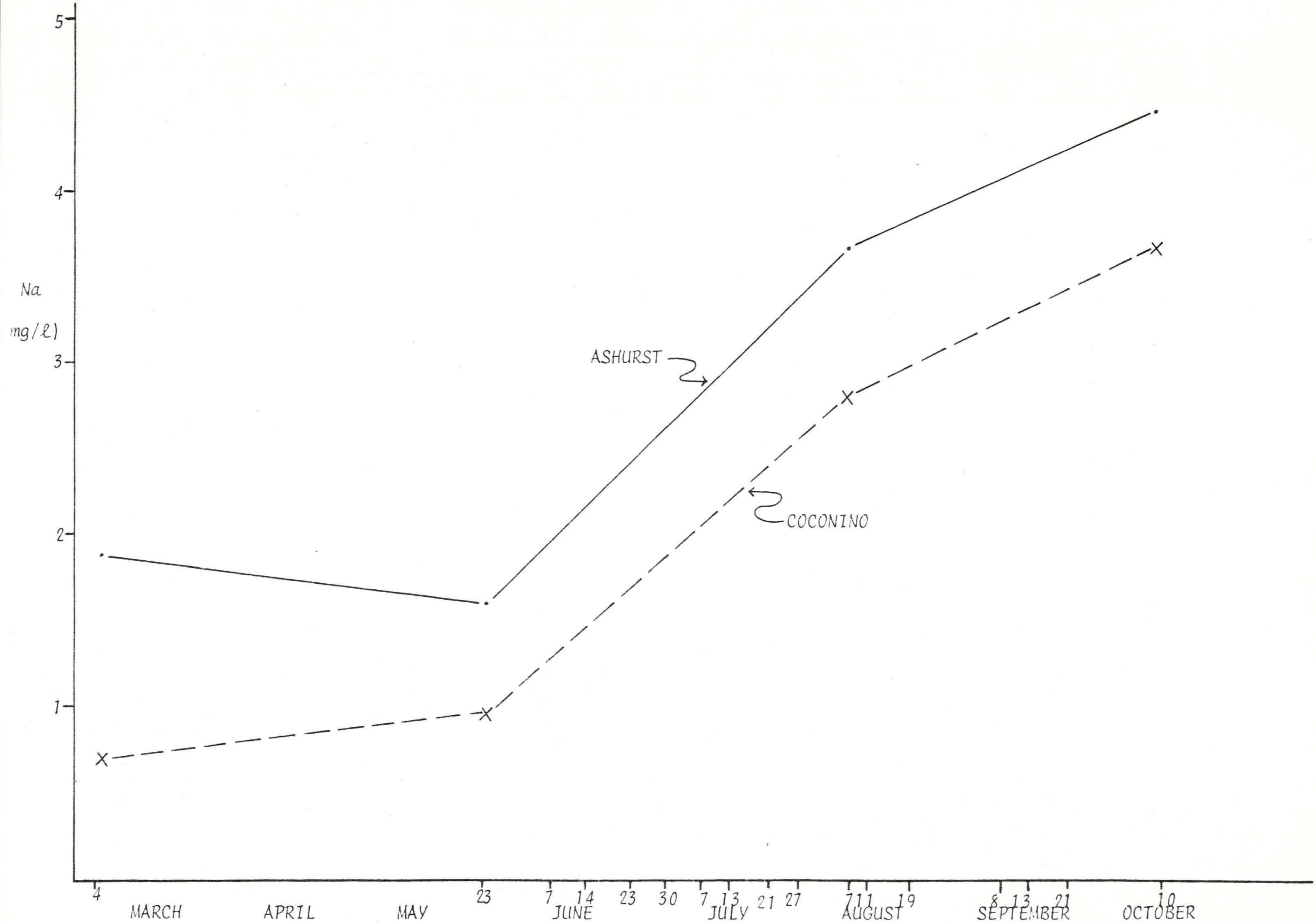
CHANGE IN MEAN Ca CONCENTRATION OVER TIME



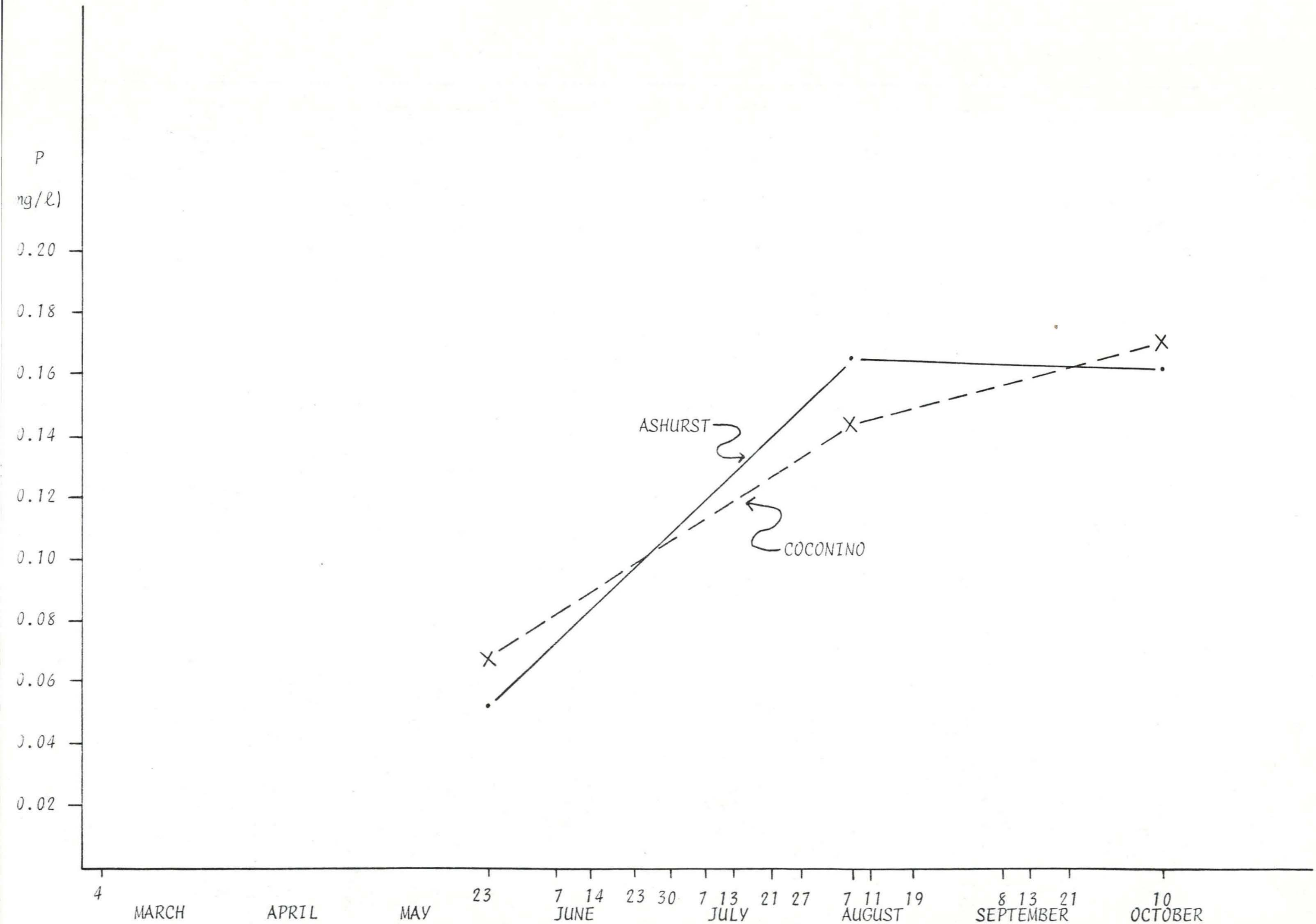
CHANGE IN MEAN Mg CONCENTRATION OVER TIME



CHANGE IN MEAN K CONCENTRATION OVER TIME



CHANGE IN MEAN Na CONCENTRATION OVER TIME



CHANGE IN MEAN P CONCENTRATION OVER TIME

STATISTICAL ANALYSIS

Pooled values for all depths and all replicates (see Appendix 2.a.) were subjected to an analysis of variance, using SPSS routines available through the NAU Computer Center.

Values for three cations showed the two water bodies to be statistically different on the four dates for which reliable data sets were available (at the .05 level): concentrations of Na, Ca and Mg were greater in Ashurst Lake than in Coconino Reservoir. Since only 2 data sets were available for use in the phosphorous analysis, the results are inconclusive for that one element. Potassium levels are generally higher in Ashurst Lake, but the difference between the two water bodies is insignificant.

The pH values (n=17) do not show a significant difference between the water bodies. The DO values were not judged to merit detailed analysis because of the dynamic nature of that parameter. Electrical conductivity values appear to underscope the different characteristics of the two lakes.

Means for each location were used in correlating nutrient values with time.

Analysis of Variance

Ashurst Lake vs Coconino Reservoir

Parameter	Computed "F"	$F_{.05}$
Potassium	1.51	4.41 Ns
Magnesium	5.19	4.38 S
Calcium	12.13	4.38 S
Phosphorus	0.64	5.12 NS
Sodium	10.31	4.38 S
pH	2.07	3.9 NS

Correlation of Selected Nutrients with Time

	-- Ashurst --			-- Coconino --		
Parameter	r	"t value"	df	r	"t value"	df
Potassium	.55	2.08*	10	.91	5.81*	7
Magnesium	.04	.12	10	.88	5.24*	8
Calcium	.88	5.86*	10	.93	7.15	8
Sodium	.90	6.5*	10	.77	3.41	8

notes

* = significant at the 95% level (2-sided)

$$t = \sqrt{\frac{n-2}{1-r^2}}$$

LAND USE DATA FOR ASHURST RUN
AND ASHURST LAKE WATERSHEDS

3.a. Inventory Data

Ashurst Run Watershed

3.b. Inventory Data

Ashurst Lake Watershed

ASHURST RUN WATERSHED

PLOT #	LOCATION	VEGETATION TYPE	BASAL AREA (sq. ft.) US	OS	SOIL PARENT MATERIAL	FORAGE DENSITY (%)	SLOPE (%)	CATTLE USE	COMMENTS
1	.9 miles south of Coc. Res. along drainage	Open bunchgrass, pinyon-juniper	0	0	Basalt	7	3	Medium	Open meadow in drainage bottom but Ponderosa pine scattered on upper slopes. Very rocky. Cattle trail following drainage.
2	2.5 miles south of pt. 1 along drainage	Open improved grasslands	0	0	Basalt	25	2	High	Planted grassland on private land. Heavily grazed with Guttierezia prominent. Few rocks.
3	1.2 miles south of pt. 2 along drainage	Open improved grasslands	0	0	Basalt	30	2	High	Planted grassland on private land. Near stock tank. Rocky in drainage bottom.
4	.9 miles south of pt. 3 along drainage	Open improved grasslands	0	0	Basalt	30	1	Medium	Planted grassland on private land. Few rocks.
5	1.4 miles south of pt. 4 along drainage	Ponderosa pine community	80	40	Basalt	15	3	Light	Ponderosa pine-Arizona fescue community. Rocky. Evidence of past logging.
6	.5 miles south of pt. 5 along southeastern drainage	Ponderosa pine community	60	80	Basalt	10	3	Light	Ponderosa pine-Arizona fescue community. Rocky.

US = understory component
OS = overstory component

PLOT #	LOCATION	VEGETATION TYPE	BASAL AREA (sq. ft. US	OS	SOIL PARENT MATERIAL	FORAGE DENSITY (%)	SLOPE (%)	CATTLE USE	COMMENTS
7	1 mile south of pt. 6 along drainage	Ponderosa pine-Gambel oak community	60	100	Basalt	10	10	Light	Ponderosa pine-Gambel oak community. Rocky. Evidence of past logging.
8	5 chains south of road near logging seep tank	Ponderosa pine-Gambel oak community	20	90	Basalt	10	15	Light	Ponderosa pine-Gambel oak community. New-mexican locust prominent. Rocky. Evidence of past logging.

See Figure 8 for locations

ASHURST LAKE WATERSHED

PLOT #	BASAL AREA (sq. ft.) US	OS	SOIL PARENT MATERIAL	FORAGE DENSITY (%)	SLOPE (%)	CATTLE USE
1	20	20	Basalt	10	3	Light
2	0	0	Basalt	15	2	Light
3	10	10	Basalt	10	5	Light
4	30	10	Basalt	10	2	Light

See Figure 7 for locations